The working volume of the crystallizer is 200 L; Rate of withdrawal of the slurry = 250 Lph; Density of the crystal: 1400 kg/m^3; volume shape factor: 0.42.

(i) Determine the crystal growth and the zero size population density of the crystal.

(ii) What is the nucleation rate?

(b) "For spontaneity in the crystallization, within the metastable zone the change in Gibb's free energy with the thickness of the zone must be constant." – Justify the statement with proper reasoning based on second law of thermodynamics.

9 + 3 =12

Group – E

8. It is required to concentrate a protein solution (MW 1213) by batch ultrafiltration from 14 kg/m^3 to 84 kg/m^3 concentration. The feed volume is 3 m^3 and the batch hours is 2 h. Membrane fouling effect and concentration polarization may be ignored. The unit is operated at 300 kPa with a rejection of 0.97. Pure water flux through membrane is equal to 0.39 m^3/m^{2}h. If the osmotic pressure is evaluated as $\pi = CRT$, where, R = 8.314 J/mol K and T = 25°C. Calculate the membrane effective surface area required.

(3 + 4 + 5) = 12

9. (a) What are the properties we should take care of during the fabrication of supported liquid membrane?

(b) A protein solution is being ultrafiltered using an asymmetric membrane having 0.3 µm active layer, 35% fractional open area and 15 nm average pore diameter. The tortuosity of the pores is 2.7. A major part of the resistance to solvent flow is offered by a gel layer which has an estimated voidage of 50%. The solvent flux is 1.2 m^3/m^{2}h at ΔP = 4 bar. If the diameter of the protein molecules is 30 nm, calculate the thickness of the gel layer. The solvent viscosity is 0.9 cP.

Given: $R_m = \frac{32\tau l_m}{\varepsilon d^2}$, where, R_m is the membrane resistance; τ is the tortuosity; l_m is the membrane thickness; ε is the membrane porosity and d is the membrane pore diameter.

The gel layer equation can be approximated with the packed bed and the gel layer resistance is given by $R_g = \frac{180(1-\varepsilon_g)^2 l_g}{d_s^2 \varepsilon_g^3}$, where, R_g is the gel layer resistance, ε_g is the gel layer porosity; l_g is the gel layer thickness; d_s is the protein molecule diameter.

(c) What is the physical significance of HLB? For a surfactant system if 25% of surfactant A (HLB = 12), 15% of surfactant B (HLB = 6) and 60% of surfactant C (HLB = 10) are mixed, then what will be the HLB of the mixed system?

4 + 5 + (1 + 2) = 12

SEPARATION PROCESS - II
(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) A UF membrane has a pore size range of
(a) 1-100A° (b) 1-100 µm (c) 1-100 nm (d) 1-100 pm.

(ii) Which of the following conditions favours the formation of large crystals?
(a) a high degree of supersaturation (b) a low nucleation rate
(c) a high magma density (d) both (b) and (c).

(iii) For a cooling tower, position of operating line should
(a) lie above equilibrium curve
(b) lie below equilibrium curve
(c) coincide with adiabatic saturation line
(d) coincide with psychrometric line.

(iv) Lewis number is the ratio of
(a) mass diffusivity to momentum diffusivity
(b) thermal diffusivity to mass diffusivity
(c) momentum diffusivity to thermal diffusivity
(d) none of these.

(v) The solvent used in liquid-liquid extraction should have _____ less than one.
(a) selectivity (b) distribution coefficient
(c) both (a) and (b) (d) neither (a) nor (b)

(vi) While drying of a solid from 33% to 1% moisture (dry basis), it is found that the constant rate drying time is the same as the falling rate drying time. The equilibrium moisture is negligible. If the falling drying rate is linear in the moisture content, what is the critical moisture content of the solid?
(a) 0.18 (b) 0.10 (c) 0.07 (d) 0.32.

(vii) For an ultrafiltration process a membrane (MWCO = 50 kDa) was employed for the separation of protein A (MW: 66000) and protein B (MW: 18000). The feed concentration is 50 ppm (with 25% (w/v) protein A). The permeate shows 1 ppm of protein A and 30 ppm of protein B. The observed rejection for A and B are
(a) 0.82,0.20 (b) 0.92,0.15 (c) 0.92,0.20 (d) 0.72,0.10.

(viii) _____ extractor uses centrifugal force for separating two phases.
(a) Kuhni (b) Podbielniak (c) Sciebel column (d) Karr column.

(ix) Recirculation of hot and humid discharged air reduces tower effectiveness for
(a) natural draft cooling tower (b) forced draft cooling tower
(c) induced draft cooling tower (d) atmospheric draft cooling tower.

(x) An air-water vapor has 60^{0}C dry-bulb temperature and 40^{0}C dew point at 1 atm. pr. The wet bulb temperature, T_w for the above mixture would be
(a) less than 40^{0}C (b) 40^{0}C (c) 40^{0}C < T_w < 60^{0}C (d) 60^{0}C.

Group – B

2. (a) Water at rate of 16 kg/s is to be cooled from 42^{0}C to 30^{0}C by contact with air in an induced draft cooling tower. Entering air has a dry-bulb temperature of 30^{0}C, wet-bulb temperature 24^{0}C. An air (with vapour) of 1.45 times the minimum is to be used. Find out the actual air rate and enthalpy of outlet airstream.

(b) Define humid heat.

(c) Obtain the equation of adiabatic cooling lines in psychrometric chart.

(5 + 4) + 1 + 2 = 12

3. (a) Write down the classification of cooling tower. Discuss the working principle of a forced draft cooling tower.

(b) In an air-conditioning system, 1 kg/s air at 350 K and 10% humidity is mixed with 5 kg/s at 300 K and 30% humidity. What is the enthalpy and humidity of the resultant stream?

(3 + 3) + 6 = 12

Group – C

4. (a) Five hundred kilograms of an aqueous feed containing 50 mass % acetone is contacted with a solvent containing 97% chloroform and rest acetone. The mass ratio of the feed to the solvent is 1.1. Calculate the mass and composition of the extract and also fraction of acetone in the feed extracted. The operation is carried out at 25^{0}C and the equilibrium and tie line data are given below:

Aqueous phase (mass fraction)			**Chloroform phase (mass fraction)**		
Water, x_A	Chloroform, x_B	Acetone, x_B	Water, y_A	Chloroform, y_B	Acetone, y_C
0.8297	0.0123	0.158	0.013	0.70	0.287
0.7311	0.0129	0.256	0.022	0.557	0.421
0.6229	0.0171	0.36	0.044	0.429	0.527
0.456	0.051	0.493	0.103	0.284	0.613
0.345	0.098	0.557	0.186	0.204	0.61

(b) How do you select solvent for liquid-liquid extraction? Define distribution coefficient.

9 + (2 + 1) = 12

5. (a) Soybean flakes containing 21 wt% oil are to be leached in a counter current multistage process to contain 0.8 kg oil/100 kg inert solid using fresh and pure hexane solvent. For every 990 kg soybeans, 1000 kg hexane is used. Experiments give the following retention of solution with the solids in the underflow, where, N is kg inert solid/kg solution retained and y_A is wt. fraction of oil in solution:

N	y_A
1.73	0
1.52	0.20
1.43	0.30

Calculate the exit flows and compositions and the number of theoretical stages needed.

(b) Define and give one example of supercritical fluid extraction. State its advantages.

8 + (2 + 2) = 12

Group – D

6. (a) Cylindrical catalyst pellets (length = diameter = 5 mm) are to be dried by the through circulation of hot air (temperature = 90°C; humidity = 0.018 kg of air/kg of dry air) at a superficial velocity of 0.8 m/s through a 30 mm thick bed of the wet pellet having 36% moisture. The solid is non-hygroscopic. The critical moisture content is 12% and the equilibrium moisture is negligible. The dried product is unloaded at 70°C with 0.2% moisture. The falling rate of drying is linear in moisture content. All moistures are on dry basis. Density of the bed of dry solid = 600 kg/m^3. Specific heat = 0.4 kJ/kg°C. The effective surface area of drying = 400 m^2/m^3. Calculate (i) the initial rate of drying (ii) the total drying time.

(b) Distinguish between (i) Free and unbound moisture (ii) Critical and equilibrium moisture.

8 + (2 + 2) = 12

7. (a) 150 g of crystals separated from 1 L of suspension from an MSMPR crystalliser is subjected to screen analysis to get the following data.

Tyler mesh	12/14	14/20	20/28	28/35	35/48	Below 48
Mass (g)	28.5	29.2	37.5	27	24.7	3.1

12 (mesh number): 1410 µm (screen opening); 14: 1190 µm; 20: 841 µm; 28: 595 µm; 35: 420 µm; 48: 297 µm.