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V 4528

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2008.

Fifth Semester

Biotechnology

BT 1304 — MASS TRANSFER OPERATIONS

(Regulation 2004)

Time : Three hours

Maximum : 100 marks

Any missing data may be assumed suitably.

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. On what factors does the mass transfer rate between two fluid phases depend?
2. Write a note on the concept of Penetration theory on diffusion and mass transfer.
3. State some common problems of packed columns.
4. What is meant by term minimum liquid – gas ratio as applied to absorption?
5. When is steam distillation recommended?
6. Define the term minimum reflux ratio.
7. What is meant by constant underflow extraction operation?
8. What is an the factor influencing the leaching process?
9. What should be properties of a good adsorbent?
10. What are the advantages of continuous drying over the batch process?

PART B — (5 × 16 = 80 marks)

11. (a) (i) Discuss the different types of diffusion occurring in various process systems. (6)
- (ii) Ammonia is diffusing through a stagnant layer gas mixture consisting of 25 percent nitrogen and 75 percent hydrogen by volume at 0° C and one atmosphere pressure. Calculate the rate of diffusion of ammonia in gm. moles/(cm² . sec.) through a gas film of 0.03 cm. thick, the partial pressure of ammonia across the film being 100 and 50 mms. Hg, respectively. The diffusivities are as follows:

$$\begin{aligned} D_{\text{NH}_3 - \text{N}_2} &= 0.148 \text{ cm}^2/\text{sec.} \\ D_{\text{NH}_3 - \text{H}_2} &= 0.580 \text{ cm}^2/\text{sec.} \end{aligned} \quad (10)$$

Or

- (b) (i) Derive a relation of steady state diffusion of a single gas through a stagnant gas layer. (8)
- (ii) A layer of water 0.1 cm thick is maintained at a constant temperature of 20°C in contact with dry air at 30°C and 1 atmosphere pressure. Assuming evaporation to take place by molecular diffusion through a gas film of 0.5 cm thick, calculate the required for water to evaporate completely.

Data : Value of diffusivity of water vapour in air = 0.262 cm²/sec.

Vapour pressure of water at 20°C = 17.5 mms.Hg. and
at 30°C = 31.8 mms. Hg. (8)

12. (a) (i) What are the factors to be taken into consideration for the choice of solvent in absorption? (6)
- (ii) A gas mixture containing 31 wt. % ammonia and 69 wt. % air is absorbed in water in a counter current packed tower. The gas and liquid flow rates on solute free basis are 2150 mol/hr m² and 5376 mol/hr m² respectively. The inlet water is pure and the exit gas contains 1.5% of the ammonia entering the tower. The equilibrium relation is $Y^* = 1.6x$, where

$$Y^* = \frac{\text{kg ammonia}}{\text{Kg air}}, \quad x = \frac{\text{kg ammonia}}{\text{kg water}}$$

Computer the number of overall gas phase transfer units. (10)

Or

- (b) (i) Compare the advantages and disadvantages of both packed towers and plate towers. (6)
- (ii) Water at the rate of 3000 kgs/hr is used for scrubbing acetone from air-acetone mixture. The temperature of water is 20°C. The mixture contains 6% acetone by volume. Air flow rate is 1400 cu.m/hr. 98% of acetone is scrubbed with water. Equilibrium relationship for acetone-water system is $y_e = 1.68x$ where y_e and x are in kg moles. Absorption of acetone takes place in a tower packed with ceramic rings of the size $25 \times 25 \times 3$ mms.
- Determine the diameter of the tower and the height of the packing required.

Data : K_y (mass transfer coefficient) = 0.40 kg mole acetone / (sq.m.hr for unit concentration gradient).

Interfacial surface area of packing is 204 sqm/cu.m. The operating velocity is 25% less than the flooding which is equal to 1.5 m/sec. (10)

13. (a) (i) Distinguish between ideal and non-ideal mixtures in gaseous phases and liquid phases. (8)
- (ii) A liquid mixture of methanol-water is boiled under a total pressure of 1,000 mm. Hg. What would be boiling temperature and equilibrium vapour composition? (8)

Data : vapour pressure data in mm. Hg at t°C.

	Temp.	93	95	97	99	101	103	104
A	MeOH	2,080	2,260	2,370	2,540	2,720	2,900	3,000
B	H ₂ O	589	634	682	733	788	847	877

Or

- (b) (i) A feed liquid consisting of 1000g moles of a mixture containing 30 mole % naphthalene (1) and 70 mole % dipropylene glycol (2) is differentially distilled at 100 mm Hg until the final distillate contains 55 mole % naphthalene (1). The VLE data at 100 mm Hg are

x_1	8.4	11.6	28	50.6	68.7	80.6	88
y_1	22.3	41.1	62.9	74.8	80.2	84.4	88

- (1) Determine the amount of distillate.
 - (2) Determine the concentration of naphthalene in the residue still liquid. (8)
- (ii) A binary mixture of n-heptane and n-octane at its boiling point containing 70 mole% of n — heptane is to be continuously distilled to give a top product of 90 mole % and a bottom product of 5 mole % n-heptane. Compute (1) Minimum reflux (2) number of theoretical plates for a reflux ratio of 3. (8)

The VLE data are:

x_H	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.90
y_H	0.182	0.333	0.461	0.571	0.667	0.75	0.82	0.89	0.95

14. (a) Water-dioxane solution is separated using benzene as solvent. The equilibrium data is given below. At these concentrations water and benzene are almost insoluble. 1000 kgs/hr of 25 percent dioxane - water solution is to be extracted to remove 95 percent of dioxane. The solvent is dioxane free. All are in weight units.
- (i) Calculate the benzene requirement for single batch operation.
 - (ii) If extraction were done with equal amounts of solvent in 3 cocurrent stages, how much solvent would be required.
 - (iii) If 900 kgs of solvent is used for counter-current extraction, how many theoretical stages are required.

Equilibrium data:

Wt. percent dioxane in water, x	5.1	18.9	25.2
Wt. percent dioxane in benzene, y	5.2	22.5	32.0

(16)

Or

- (b) Copper Sulfate in roasted ore is to be leached with water in continuous counter current extraction cascade. 100 tons per day of ore containing 9% CuSO_4 , 86% insoluble gangue and 5% moisture is leached. The strong extract solution will contain 10% CuSO_4 and 90% water. Since CuSO_4 is the valuable constituent, 95% of it must be recovered in the extract. The gangue retains 1.5 tons of water per ton of gangue

- (i) Calculate number of equilibrium stages required without using graphical method.
- (ii) What is the flow rate of water to the cascade? (16)
- (iii) Calculate the total net flow at each stage.
15. (a) (i) Explain the principle of a rotary drier and give an example of industries where it is used. (6)
- (ii) A product of 1.0 gm per cc density when dry is to be dried in a batch tray drier from a moisture content of 0.8 kg water/kg wet solid to 0.08 kg water per kg wet solid. Trays are 50 cm × 50 cm × 1.5 in size and arranged so that drying occurs from the top surface only with bottom surface insulated. Air at a temperature of 75°C dry bulb and 50°C wet bulb temperature circulates across the pan surface at the mass velocity of 8000 kg/(hr.sq m). Previous experience under the similar drying conditions indicates that the critical moisture content will be 0.45 kg water per kg dry solid and the equilibrium moisture content will be 0.03 kg water per kg dry solid. The drying rate during the falling rate period will be proportional to the free moisture content. Determine the drying time required.

Heat transfer equation:

$$h = 0.071 G^{0.8} \text{ where } G = \text{mass flow rate of air, kg/(hr.sq m)}$$

$$h = \text{total heat transfer coefficient from air to solid, kJ/(hr sq m}^\circ \text{C)} \quad (10)$$

Or

- (b) (i) Compare the several adsorption isotherms and discuss their significance in the process systems. (6)
- (ii) Experiments on decolourization of oil yielded the following equilibrium relationship:

$$\text{Where } y = 0.5 x^{0.5}$$

$$y = \text{gm of colour removed/gm of adsorbent}$$

$$x = \text{colour in the oil, } \frac{\text{gm of colour}}{1000 \text{ gm of colour - free oil}}$$

100 kg oil containing 1 part of colour to 3 parts of oil is agitated with 30 kg of the adsorbent Calculate the % of colour removed if

- (1) all 30 kg adsorbent is used in one step and
- (2) 15 kg adsorbent is used initially, followed by another 15 kg of adsorbent.

(10)