Register Number:……..

KUMARAGURU college of technology
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B.TECH. DEGREE EXAMINATIONS: NOV/DEC 2023

(Regulation 2018)

Fifth Semester

BIOTECHNOLOGY

U18BTI5203:Heat and Mass Transport in Bioprocess

COURSE OUTCOMES

CO1: Outline the modes of heat of transfer
CO2: Design the heat transfer equipment in bioprocess industries
CO3: Illustrate the principles of diffusion and apply the concepts of interphase mass transfer in bioreactor
CO4: Apply the concept of distillation and drying in bioprocess
CO5: Comprehend the extraction separation in bioprocess
CO6: Interpret the membrane separation in bioprocess

Time: Three Hours **Maximum Marks: 100**

Answer all the Questions

PART A (10 x 2 = 20 Marks)

(Answer not more than 40 words)

1.	The heat flux (from outside to inside) across an insulating wall with thermal conductivity k = 0.04 W/m K and thickness 0.16 m is 10 W/m^2. The temperature of the inside wall is –5°C. Calculate the outside wall temperature.	CO1	[K_3]
2.	The thermal radiative flux from a surface of emissivity = 0.4 is 22.68 kW/m^2 and Stefan Boltzmann's constant = 5.67 x 10^{-8} W/m^2 k^4. Determine the approximate surface temperature.	CO1	[K_2]
3.	A fluid is heated from 40°C to 60°C in a countercurrent, double pipe heat exchanger. Hot fluid enters at 100°C and exits at 70°C. Calculate the log mean temperature difference (in °C) (LMTD).	CO2	[K_3]
4.	An aqueous sodium chloride solution (10 wt %) is fed into a single effect evaporator at a rate of 10000 kg/hr. It is concentrated to a 20 wt % sodium chloride solution. The rate of consumption of steam in the evaporation is 8000 kg/hr. Evaluate the economy of evaporator.	CO2	[K_2]
5.	List the factors affecting of oxygen transfer rate in bioreactor	CO3	[K_2]
6.	Outline the penetration theory by Higbie.	CO3	[K_1]
7.	An equimolar mixture of A and B (A being more volatile) is flash distilled continuously at a feed rate of 100 k mol/h, such that the liquid product contains 40 mol% of A. If the relative volatility is 6, Calculate the vapor product, in k mol/h.	CO4	[K_2]
8.	Define equilibrium moisture content.	CO4	[K_1]
9.	What is meant by distribution coefficient?	CO5	[K_1]
10.	Recall the different types of membrane and classifications.	CO6	[K_1]

Answer any FIVE Questions

PART B (5 x 4 = 20 Marks)

(Answer not more than 80 words)

11.	The inner wall of a furnace is at a temperature of 700°C. The ambient air is at 30 ^{0}C and the heat transfer coefficient between the outer surface of wall and air is 20 W m^{-20} C^{-1}.The composite wall is made of two substances, 10 and 20 cm thick with thermal conductivities of 0.05 and 0.1 W m^{-10} C^{-1} respectively.Calculate rate of heat loss from the outer surface in Wm^{-2}	CO1	[K_3]
12.	A perfectly insulated double pipe heat exchanger is operating at steady state at counter flow. Saturated steam enters the inner pipe at 100°C and leaves as saturated water at 100°C. Cooling water enters the outer pipe at 75°C and exits at 95°C. The overall heat transfer coefficient is 1 kW m^{-2} K^{-1} and the heat transfer area is 1 m². The average specific heat capacity of water at constant pressure is 4.2 kJ kg^{-1} K^{-1}. Calculate the required cooling water flow rate in kg s^{-1}.	CO2	[K_3]

13. Discuss about how would you optimize the mass transfer process to ensure efficient utilization of the substrate and enhance the product yield in the fermentation process — CO3 [K_3]
14. A mixture of benzene and toluene boils at 368 K (95°C) under a pressure of 101.325 kPa. Determine the composition of the boiling liquid assuming that mixture obeys Raoult's law. At 368 K (95°C), the vapour pressure of benzene is 155.56 kPa and that of toluene is 63.98 kPa — CO4 [K_3]
15. Illustrate the qualities to be consider for selecting a solvent for extraction. — CO5 [K_2]
16. Demonstrate the preparation of a porous membrane by track etching with neat diagram. — CO6 [K_2]

Answer any FIVE Questions

PART C (5 x 12 = 60 Marks)

(Answer not more than 300 words)

17. a) A circular tube of outer diameter 5 cm and inner diameter 4 cm is used to convey hot fluid. The inner surface of the wall of the tube is at a temperature of 80°C, while the outer surface of the wall of the tube is at 25°C. What is the rate of heat transport across the tube wall per meter length of the tube of steady state, if the thermal conductivity of the tube wall is 10 W/(m K)? — 6 CO1 [K_3]

    b) The bottom face of a horizontal slab of thickness 6 mm is maintained at 300 °C. The top face is exposed to flowing gas at 30 °C. The thermal conductivity of the slab is.5 W m K and the convective heat transfer coefficient is 30 W m^{-2} K^{-1}. At steady state, Calculate the temperature (in °C) of the top face. — 6 CO1 [K_3]

18. a) With a neat diagram, explain the plate heat exchangers and shell and tube heat exchangers. Highlight their advantages and disadvantages. — 8 CO2 [K_3]

    b) Compare the principles of autoclaving and heat sterilization — 4 CO2 [K_3]

19. a) Illustrate the various stages oxygen of transfer rate from the bulk phase to a cell within a bio reactor using on neat diagram. — 6 CO3 [K_2]

    b) List the factors influencing oxygen transfer in a bioreactor and methods for measuring the oxygen mass transfer Co-efficient ($K_L a$). — 6 CO3 [K_2]

20. a) A mixture of benzene and toluene containing 60 mole % benzene is to be separated to give a product of 95 mole % benzene and a bottom product containing 10 mole % benzene. The feed enters a column at its bubble point. It is proposed to operate the column with reflux ratio of 2.5. It is required to find the number of theoretical plates needed. Equilibrium data: — 6 CO4 [K_4]

x	0	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
y	0	0.13	0.21	0.375	0.5	0.6	0.7	0.77	0.83	0.9	0.95	1.0

    b) A wet solid containing 20% (w/w) moisture (based on mass of a bone-dry solid) is dried in a tray dryer. The critical moisture content of the solid is 10% (w/w). The drying rate (kg m^{-2} s^{-1}) is constant for the first 4 hours and then decreases linearly to half the initial value in the next 1 hour. At the end of 5 hours of drying, calculate the percentage moisture content of the solid. — 6 CO4 [K_3]

21. a) Which type of extraction equipment is used for atomic energy work, petroleum and metallurgical industries? Extend the working principle with neat diagram. — 6 CO5 [K_2]

    b) 100 kg of a feed containing 50 wt.% of a solute C is contacted with 80 kg of a solvent. containing 0.5 wt.% of C in a mixer-settler unit. From this operation, the resultant extract and raffinate phases contain 40 wt.% and 20 wt.% of C, respectively. If E and R denote the mass of the extract and raffinate phases, respectively, Calculate the ratio E/R. — 6 CO5 [K_3]

22. a) Summarize the basis of dead-end filtration and cross flow filtration in the membrane separation with neat sketch. — 6 CO6 [K_2]

    b) Explain the technique of pervaporation with neat flow diagram. — 6 CO6 [K_2]

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