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Question Paper Code: 2375268

B.E. / B.Tech. DEGREE EXAMINATIONS, NOV/ DEC 2024

Fifth Semester

Pharmaceutical Technology

U20PT504 – HEAT AND MASS TRANSFER OPERATIONS IN PHARMACEUTICAL TECHNOLOGY

(Regulation 2020)

Time: Three Hours Maximum: 100 Marks

Answer ALL questions

PART – A (10 x 2 = 20 Marks)

1. Define steady-state heat conduction with an example.
2. Relate the role of extended surfaces (fins) in enhancing heat transfer?
3. Define the Nusselt number and explain its significance in convection.
4. Compare film and dropwise condensation.
5. Compare and contrast black and gray bodies in terms of radiation exchange.
6. State Kirchhoff's law of thermal radiation.
7. State Fick's first law of Diffusion.
8. Define Eddy diffusion. Mention its significance in mass transfer.
9. Compare staged and continuous extraction.
10. Show the factors that influence the efficiency of leaching equipment.

PART – B (5 x 16 = 80 Marks)

11. (a) (i) Derive the temperature profile for steady-state heat conduction through a hollow sphere. Assume the sphere has inner radius r_1 and outer radius r_2, with known temperatures T_1 and T_2 at the inner and outer surfaces, respectively. (8)

(a) (ii) A hollow sphere has an inside surface temperature 573 K and the outside surface temperature 303 K. Find the heat loss by conduction for an inside diameter of 50 mm and outside diameter of 150 mm. The thermal conductivity of material is 17.45 W/(m·K). (8)

(OR)

(b) A 300 mm OD pipe is covered with two layers of insulation (k_1=0.105 W/m.K and k_2=0.07 W/m.K). The better insulating material is on the outside and is 40 mm thick. The other insulating material is of 50 mm thickness. The inner and outer surface temperatures of the insulation are 623 K and 323 K. Estimate:
i. Heat loss per meter length.
ii. Heat loss per square meter of outer insulation surface.
iii. Temperature of the surface between the two layers of insulation

(16)

12. (a) Contrast the different types of feed arrangements in multiple-effect evaporators and explain their key features. Provide examples of industrial applications where each feed type is preferred and justify their selection based on operational efficiency. (16)

(OR)

(b) Cold fluid is flowing through the heat exchanger at a rate of 15 m^3/h. It enters the heat exchanger at 303 K and leaves at 328 L. A hot thermic fluid enters the heat exchanger at a rate of 21 m^3/h at a temperature of 388 K. Find the area of heat transfer required assuming the flow to be counter current and overall heat transfer coefficient be 3490 W/(m^2·K). Densities of cold and thermic fluid are 1000 kg/m^3 and 950 kg/m^3 respectively. 4.187 kJ/(kg·K) and 2.93 kJ/(kg·K) are Specific heats of cold and thermic fluids respectively. (16)

13. (a) Demonstrate the design of shell and tube heat exchangers and multipass exchangers with a neat sketch. Explain their working principles and apply this knowledge to analyze the advantages of using multipass exchangers in industrial applications. (16)

(OR)

(b) An evaporator is to be fed with 5000 kg/h solution containing 10% solute by weight. The feed at 313K is to be concentrated to a solution containing 40% by weight of the solute under an absolute pressure of 101.325 kPa. Steam is available at an absolute pressure of 303.975 kPa (saturation temperature of 407 K). The overall heat transfer coefficient is 1750 W/m^2K. (16)
Calculate
(i) heat transfer area that should be provided;
(ii) economy of an evaporator.
Data: C_p of feed = 4.187 kJ/Kg.K
Treat solution as pure water for the purpose of calculation of enthalpies.

Temperature, K	Enthalpy, kJ/Kg	
	Vapour	**Liquid**
313	---	170
373	2676	419
407	2725	563

14. (a) Derive the equation for Steady state diffusion using Fick's first law of diffusion and explain how it applies to molecular diffusion in gases. Provide an example of its application in industry. (16)

(OR)

(b) (i) A thin film 0.4 cm thick of an ethanol – water solution is in contact at 20°C at one surface with an organic liquid in which water is insoluble. The concentration of ethanol at the interface is 6.8% (w/w) and at the other side of film it is 10.8% (w/w). The densities are 0.9881 g/cc and 0.9728 g/cc respectively for 6.8% (w/w) and 10.8% (w/w) ethanol solutions. Diffusivity of ethanol is 74 x 10^{-5} cm^2/s. Calculate the steady state flux in k mole /m^2 s. (8)

(b) (ii) At 293 K the solubility of ammonia in water is given by $p = 0.3672\ C$, where, p is in atmosphere and C is in k mole/m^3. A mixture of 15% Ammonia and 85% air by volume at $1\ atm$ is in contact with an aqueous solution containing 0.147 gmole /lit. The air velocity is such that $\frac{k_G}{k_L} = 0.9$. Find the concentration of ammonia and partial pressure at interface. (8)

15. (a) Nicotine in a water solution containing 1% nicotine is to be extracted with kerosene at 20°C. The kerosene and water are insoluble. Using both analytical and graphical methods, determine the percentage extraction if 1000 kg of feed solution is extracted once with 1500 kg of solvent. Additionally, calculate the percentage extraction if three ideal stages are used with 500 kg of solvent in each stage.

Use the following equilibrium data:

X	0	0.00101	0.00246	0.00502	0.00751	0.00998	0.0204
Y	0	0.00081	0.001962	0.00456	0.00686	0.00913	0.0187

Where:

- X is the concentration of nicotine in the aqueous phase (kg Nicotine/kg water),
- Y is the concentration of nicotine in the kerosene phase (kg Nicotine/kg kerosene).

(16)

(OR)

(b) Identify the principles, setup, and applications of percolation leaching. Provide examples of industries utilizing this method, including its advantages and challenges. (16)

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