3. Attempt any two part:

(a) A mixture of nitrogen and acetone vapour at 101.325 kPa and 27°C has a percentage saturation of 75%. Calculate its relative saturation and dew point. Vapour pressure of acetone is given by:

$$\ln P^{sat} = 14.7171 - \frac{2975.95}{T - 34.5228}$$

where p^{sat} = vapour pressure of acetone, kPa

T = temperature, K. 10

(b) Air at 1 atm is blown past the bulb of a mercury thermometer. The bulb is covered with a wick. The wick is immersed in an organic liquid (molecular weight = 58). The reading of the thermometer is 7.6°C. At this temperature, the vapour pressure of the liquid is 5 kPa. Find the air temperature, given that the ratio of the heat transfer coefficient to the mass transfer coefficient (psychrometric ratio) is 2 kJ/kg K and the latent heat of vaporization of the liquid is 360 kJ/kg. Assume that the air, which is blown, is free from the organic vapour. 10

(c) Differentiate between the following:

(i) Partial pressure and vapour pressure

(ii) Dry-bulb temperature and wet-bulb temperature

(iii) Natural-draft and forced draft cooling tower

(iv) Dew point and adiabatic saturation temperature 10

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ECH501

(Following Paper ID and Roll No. to be filled in your Answer Book)

PAPER ID : 151502

Roll No.

B.Tech. (Semester-V)

SPL. THEORY EXAMINATION, 2014-15

MASS TRANSFER OPERATION-I

Time : 3 Hours] *[Total Marks : 100*

Note: Attempt all questions.

1. Attempt any two parts.

(a) What are the general principles underlying the two-film and penetration theories for mass transfer across the phase boundary? Give the basic differential equations with appropriate boundary conditions. 10

(b) Oxygen is diffusing through a stagnant layer of carbon monoxide. The total pressure is 10^5 N/m^2 and the temperature is 0°C. The partial pressures of oxygen at two planes 5 mm apart are 13000 N/m^2 and 6500 N/m^2, respectively. The rate of diffusion of oxygen is 3×10^{-5} kmol/s m^2. Estimate the diffusion coefficient of oxygen-carbon monoxide mixture. 10

(c) The mass flux from a 5 cm diameter naphthalene ball, placed in stagnant air at 40°C and atmospheric pressure, is 1.47×10^{-3} mol/m^2 s. Assume the vapour pressure of naphthalene to be 0.15 atm at 40° C and negligible bulk concentration of naphthalene in air. If air starts blowing across the surface of naphthalene ball at 3 m/s, by what factor will the mass transfer rate increase, all other conditions remaining the same.

For spheres: $Sh = 2.0 + 0.6 (Re)^{0.5} (Sc)^{0.33}$

where Sh is the Sherwood number, Re is the Reynolds number and Se is the Schmidt number. The viscosity and density of air are 1.8×10^{-5} kg/m s and 1.123 kg/m^3, respectively and the gas constant is 82.06 cm^3 atm/mol K. 10

2. Attempt any <u>four</u> parts:

(a) State Henry's law. What are its limitations? Discuss the effect of temperature and pressure on the solubility of a gas in a liquid. 5

(b) Derive the following relation with explanation of each term:

$$HTU_{OL} = HTU_L + \left(\frac{L}{mG}\right) HTU_G$$ 5

(c) A waste-air stream containing 2 mol% of impurity A is purified to 0.02 mol% by scrubbing with pure water in a countercurrent packed column. The column provides 7 overall gas-phase transfer units in a height

of 1.75 m. The equilibrium mole fractions of A in the vapour and liquid are related according to:

$$y_A = 1.75 x_A$$

Find HTU_{OG} and L/G ratio. 5

(d) An alkaline solution is used to reduce the concentration of carbon dioxide in a stream from 10% to 0.1% by absorption with irreversible chemical reaction. Find the number of overall gas phase transfer units. 5

(e) The number of overall gas-phase transfer units in a continuous-contact packed column is given by:

$$NTU_{OG} = \int_{y_2}^{y_1} \frac{(1-y)_{*M}}{(1-y)(y-y^*)} dy$$

In this equation replace y's by the equivalent Y's and derive the following equation:

$$NTU_{OG} = \int_{Y_2}^{Y_1} \frac{dY}{(Y-Y^*)} + \frac{1}{2} \ln \frac{1+Y_2}{1+Y_1}$$

if $(1-y)_{*M}$ can be taken as the arithmetic mean of $1-y$ and $1-y^*$ and y is defined by $Y = \frac{y}{1-y}$. 5

(f) Define and give the significance of the following in the design of absorption column: (i) Flooding velocity (ii) Theoretical (equilibrium) stage (iii) Absorption factor. 5

4. Attempt any two parts:

(a) The following observations have been obtained while drying a wet solid slab:

(i) Weight of wet solid = 200 kg

(ii) Initial moisture content = 30% (wet basis)

(iii) Final moisture content = 5% (wet basis)

(iv) The rate of drying was constant at 3×10^{-4} kg water/m^2 s in the region 0.2~0.4 kg water/kg bone dry solid.

(v) The rate of drying has a linear falling rate after the constant-rate period.

(vi) The equilibrium moisture content = 0.01 kg water/kg bone dry solid.

(vii) The total drying surface area is 10 m^2.

Estimate the total time of drying. 10

(b) Drying of a food product is carried out in an insulated tray. The drying surface has a partial pressure of water equal to 2360 Pa and a wet-bulb temperature of 30°C. The product has a drying surface of 0.05 m^2/kg dry solid. The material has a critical moisture content of 0.12 (dry basis) and negligible equilibrium moisture content. The drying rate in the falling rate period is proportional to the moisture content and the mass-transfer coefficient is 5.34×10^{-4} kg/m^2h Pa. Calculate:

(i) the drying rate in the constant-rate period in kg/m^2 h.

(ii) the time required to dry the material from a moisture content of 0.22 to 0.06 (both on dry basis). Vapour pressure of water at 30°C = 4232 Pa. 10

(c) Define equilibrium moisture content, bound moisture content, unbound moisture content, free moisture content, rate of drying. With the help of a neat sketch, explain the construction and operation of a spray dryer. 10

5. Attempt any two parts:

(a) Explain the theory of supersaturation and nucleation in crystallization. 10

(b) With the help of a neat sketch, describe the construction and operation of draft tube baffle (DTB) crystallizer. 10

(c) A 35 wt% Na_2SO_4 solution in water, initially at 50°C, is fed to a crystallizer at 20°C. The product stream contains hydrated crystals $Na_2SO_4 \cdot 10H_2O$ in equilibrium with a 20 wt% Na_2SO_4 solution. 500 kg/h of hydrated crystals are to be produced.

(i) Calculate the mass flow rate of 35 wt% Na_2SO_4 solution required.

(ii) Calculate the mass flow rate of 20 wt% Na_2SO_4 solution produced.

10

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