B. CHEM. 3RD YEAR 1ST SEM. EXAMINATION 2017

Separation Process - I

Time: Three hours | Full Marks: 100

*Answer **any five** questions. All questions carry equal marks.*
Assume any missing data.
Write all assumptions clearly.

1. a) In the absorption of NH_3 in wetted-wall column, the overall mass transfer coefficient K_G = 1.001 kmol/hr.m^2.atm. At a point in the column, the gas contains 8mol% NH_3, whereas the NH_3 concentration in the liquid at the same position is 0.064 kmol/m^3 of solution at 20°C and 1atm pressure. It is given that 85% of the total resistance to mass transfer lies in the gas phase. Henrey's law constant for $NH_3 - H_2O$ system is 0.0134 atm/kmol.m^3. Find the interfacial liquid and gas phase concentration. What type of contacting device will you prefer for the above mentioned problem and why?

   b) What type of flow configuration will you prefer for large diameter column? What are the disadvantages of cross-flow trays under the above circumstances?

   d) It is observed that the liquid level in a down-comer is always high compared to that on adjacent plate – Explain.

   10+5+5 = 20

2. a) A plant design calls for an absorber that is to recover 95% of acetone in an air stream using water as absorbing liquid in a plate column absorber at 27°C and 1atm pressure. The entering air contains 14 mol% of acetone and the water fed to the tower contains 0.02 mol% acetone. The tower is to be designed to operate at 1.5 times the minimum liquid velocity. (a) Find the liquid flow rate if the gas velocity is 100Nm^3/min. (b) Find the number of theoretical stage. (For equilibrium, assume $p_A = P_A^0 \gamma_A x$, where $\ln \gamma_A = 1.95(1-x)^2$. The vapour pressure of acetone at 27°C is 0.33 atm).

   b) A spherical gas bulb of volume 500cc contains air – NH_3 mixture in the volume ratio of 4:1 at 40°C and 1atm pressure. It is exposed to the atmosphere at the same temperature and pressure through a capillary of length 5cm and diameter 1.0mm. If this gas bulb is left open as such, find the ammonia concentration in the bulb after 20 minutes. Given: D_{AB} for air – NH_3 at 0°C and 1atm pressure is 0.198×10^{-4} m^2/s.

   c) Definition of k-type mass transfer coefficient for equimolar counter-diffusion is exact, but that for diffusion of A through stagnant B is approximate – Explain.

   10+7+3 = 20

3. a) Suppose a raindrop is falling through air. Which model will you prefer for determination of evaporation rate from falling raindrop? Explain.

   b) What are the basic differences between the film theory and penetration theory of mass transfer across phase boundary?

   c) Consider the absorption of methanol from air-methanol mixture into liquid water. The air contains 5 mol% methanol and 98% absorption is required. The gas flow rate is 1,200 Nm^3/h. It is proposed to carry out the operation at 40°C and 1atm in bubble-plate tower fitted with cross-flow tray. Take the solvent flow rate to be 1.7 times the minimum. The equilibrium relationship may be assumed to follow the following linear relation: $y^* = 1.0682x$.
   i) Find tower diameter. Given: Flooding constant = 0.0909, tray area occupied by one downspout = 9% and take operating gas velocity to be 75% of the flooding velocity.
   ii) Find the number of plates if Murphree vapor phase efficiency is given to be 70%.

   5+5+10 = 20

4. a) In the case of "diffusion of A through stagnant B" concentration profile is observed for the component B along the diffusion path, though it is not diffusing. How can you explain this phenomenon?

   b) Water at the rate of 4,000kg/hr is used for scrubbing a solute gas (say, A) from its mixture with air containing 15% component A by volume. The gas is flowing at the rate of $1500m^3/hr$ at 20°C, 1atm and 90% removal of the component A is to be achieved by absorption in a packed absorption column operating at 20°C and 1atm pressure. The equilibrium relation is given by $y = \frac{ax}{a+x(a-1)}$, where $a = 1.2$. The flooding velocity is 1.56m/s and the operating velocity is 60% of the flooding velocity. The overall mass transfer coefficient on volume basis is $81.6kmol/hr.m^3.atm$. Calculate the height and diameter of the packed column required for the above purpose.

   c) How will you calculate the diffusion rate of a solute in a multicomponent gaseous mixture? What will be the case when only one component is diffusing in a stagnant mixture?

   5+5+10 = 20

5. a) Why does a big natural draft cooling tower have a hyperbolic shape?

   b) What kinds of water loss occur during cooling in a tower? What is blow down? Why is it done?

   c) A cooling tower is to be designed to cool water from 45°C to 30°C by counter-current contact with air of dry bulb temperature 30°C and wet-bulb temperature of 25°C. The water rate is 5,500 $kg/m^2.h$ and the air rate is 1.25 times the minimum. Determine the tower height if the individual gas phase mass transfer coefficient k_Ya is 5,743.5 $kg/m^3.h.(\Delta Y)$. The volumetric water-side heat transfer coefficient is given by $h_L a = 0.059L^{0.51}G_s$ in $kcal/m^3.h.K$, where L and G_s are mass flow rates of water and air (dry basis) respectively. Psychrometric chart may be used.

Antoine's equation:

$$\ln P_A^v = 11.96481 - \frac{3984.923}{T - 39.724}$$

where, P_A^v is the vapour pressure in bar and T is the temperature in Kelvin. The total pressure may be assumed to be 1 atm.

3+5+12 = 20

6. a) Derive the equations for calculation of constant rate drying time and falling rate drying time in case of "Through-circulation drying".

   b) What is the mechanism of moisture transport in case of drying in different solids?

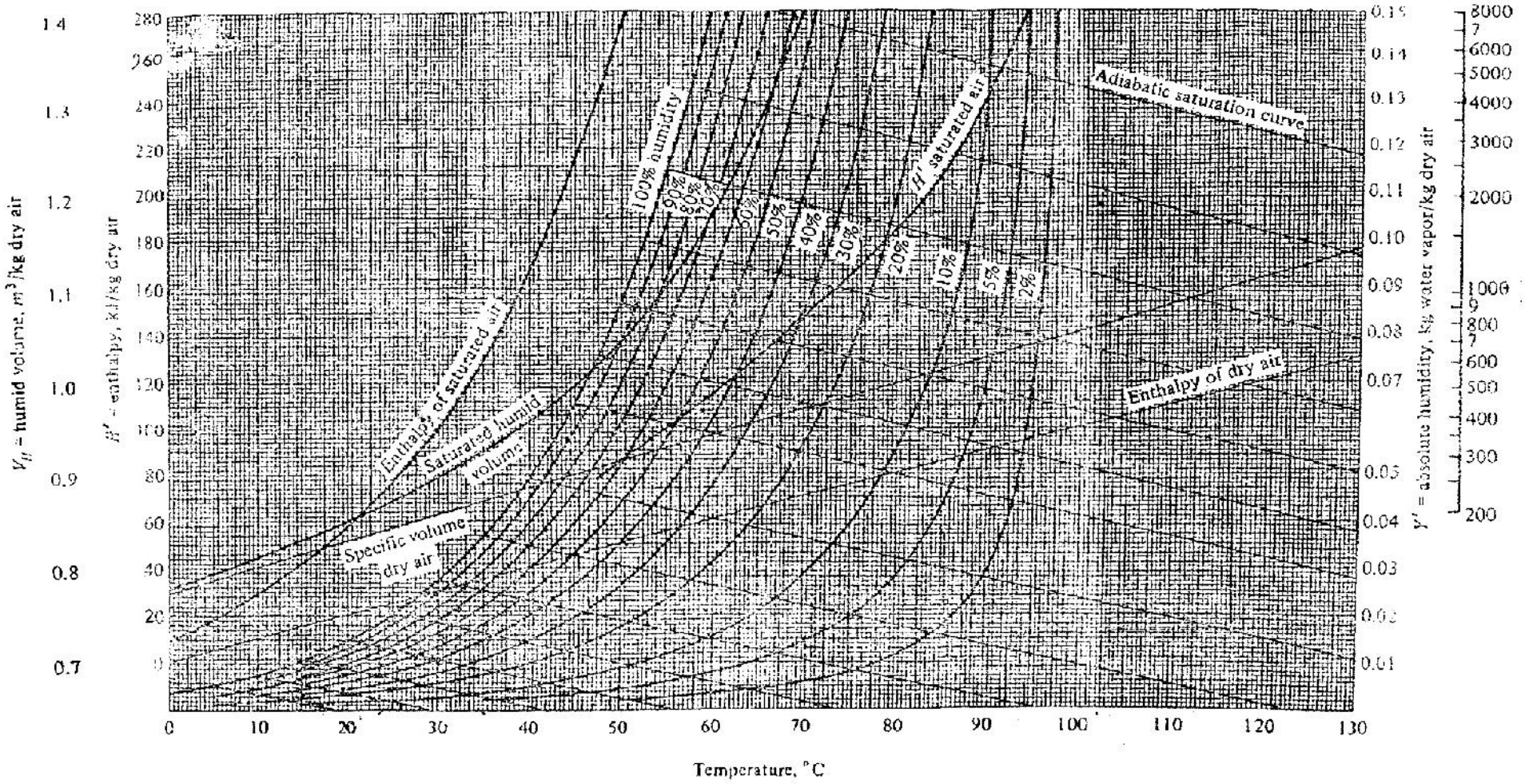
   c) A wet solid of 28% moisture is to be dried to 0.5% moisture in a tray dryer. A laboratory test shows that it requires 8 hours to reduce the moisture content of the same solid to 2%. The critical moisture content is 6% and the equilibrium moisture is 0.2%. The falling rate of drying is linear in the free moisture content. Calculate the drying time of the solid if the drying conditions similar to those in the laboratory test are maintained. All moistures are expressed as per cent of "bone dry" mass of the solid.

6+4+10 = 20

7. Write short notes on **any four**:

   i) Drying rate curve
   ii) Different types of moisture in a wet solid
   iii) Classification of cooling tower
   iv) Cooling Range and Approach
   v) Dankwerts' Surface Renewal Theory
   vi) Toor and Marchello film – penetration theory
   vii) Justify the statement that true driving force in mass transfer operation is chemical potential, not the concentration difference.
   viii) Assumptions in the determination of diffusivity by Stokes – Einstein equation.
   ix) Justify: We can assume total concentration to remain constant in gaseous mixture while in diffusive mass transfer if the total pressure is constant along the diffusion path, but the same is not true for liquid phase.

4 x 5 = 20



Psychrometric chart for air-water vapor, 1 std atm abs, in SI units.