Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech (CHE)/SEM-5/CHE-505/2011-12

2011
SEPARATION PROCESSES-I

Time Allotted : 3 Hours *Full Marks* : 70

The figures in the margin indicate full marks.
Candidates are required to give their answers in their own words as far as practicable.

GROUP – A
(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

   i) The diffusivity (D) in a binary gas mixture is related to the temperature (T) as

   a) $D \propto T$ b) $D \propto T^{0.5}$

   c) $D \propto T^{1.5}$ d) $D \propto T^{2}$.

   ii) Corresponding to Nusselt number in heat transfer, the dimensionless group in mass transfer, is

   a) Sherwood number b) Schmidt number

   c) Peclet number d) Stanton number.

   iii) In a binary distillation column if the feed contains 40 mol% vapour, the q line will have a slope of

   a) 1·5 b) – 0·6

   c) – 1·5 d) 0·6.

iv) In the event of severe weeping, no liquid reaches the downspouts. This phenomenon is known as

a) priming b) coning

c) dumping d) none of these.

v) For BET model of adsorption, it is assumed that

a) Heat of adsorption = Heat of liquefaction

b) Heat of adsorption > Heat of liquefaction

c) Heat of adsorption < Heat of liquefaction

d) Heat of adsorption = 2* Heat of liquefaction.

vi) Which of the following assumes constant molal vaporization and overflow ?

a) McCabe-Thiele method

b) Ponchan-Savarit method

c) Enthalpy concentration method

d) Plate absorption column.

vii) As the reflux ratio is increased, the intersection of both the operating lines

a) moves towards the diagonal

b) moves away from the diagonal

c) does not at all move

d) none of these.

viii) At the azeotropic composition of a binary mixture, the relative volatility is

a) 0 b) infinite

c) 1 d) < 1.

ix) The ratio of Murphree plate efficiency to point efficiency is 1 in which of the following models ?

a) Plug

b) Perfectly mixed

c) Both (a) and (b)

d) Neither (a) nor (b)

x) Maximum boiling azeotropism may occur if there is

a) positive deviation from ideality

b) negative deviation from ideality

c) no deviation from ideality

d) none of these.

xi) Pores of an adsorbent may be classified as *micropores* if diameter of pores is

a) $500\ \mathring{A}$

b) $20 - 500\ \mathring{A}$

c) $< 20\ \mathring{A}$

xii) Molecular sieves are

a) porous form of SiO_2

b) obtained by destructive distillation of wood

c) porous synthetic zeolite crystals of metal alumino-silicates

d) porous form of aluminium oxide.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. 3 × 5 = 15

2. Write a short note on 'Mass Transfer Zone in a Packed Bed Adsorption Column'.

3. Briefly discuss important properties of adsorbent. Give a few examples of commonly used adsorbents.

4. Derive equation for determination of height of packed absorption tower in terms of HTU and NTU.

5. A sphere of naphthalene having a radius of 2·0 mm is suspended in a large volume of still air at 318 K and $1{\cdot}01325 \times 10^5$ Pa (1 atm). The surface temperature of the naphthalene can be assumed to be at 318 K and its vapour pressure at 318 K is 0·555 mm Hg. The D_{AB} of naphthalene in air at 318 K is $6{\cdot}92 \times 10^{-6}$ m^2/s. Calculate the rate of evaporation of naphthalene from the surface.

6. Show that Freundlich isotherm is a special case of Langmuir isotherm.

7. What is relative volatility ? To what extent does the separation take place by distillation if the relative volatility equals one ? Derive an equation for an ideal mixture based on relative volatility (α). 1 + 1 + 3

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 = 45$

8. a) An unglazed porcelain plate is 5 mm thick and average pore diameter is of 0·2 μm. Pure oxygen gas at 20 mmHg pressure and 273 K temperature on one side passes through the plate at a rate of 0·093 c.c./cm^2-s when the pressure in the downstream side was so low as to be considered negligible. Estimate the rate of diffusion of hydrogen through the plate at 10 mmHg pressure and 298 K temperature with negligible downstream pressure. Consider the viscosity of oxygen and hydrogen are 0·02 C_p and 0·0085 C_p respectively.

b) Calculate the rate of diffusion of acetic acid across a film of non-diffusion water solution 2 mm thick at 17°C, when the concentrations on the opposite sides of the film are 9% and 3% acid (by weight). The diffusivity of acetic acid in the solution is $0{\cdot}95 \times 10^{-9}$ m^2/s. Densities of 9% and 3% by weight acid are 1012 kg/m^3 and 1003 kg/m^3 respectively. 8 + 7

9. a) Discuss the methods for calculation of height and diameter of an Absorption column.

b) A mixture of acetone vapour and air containing 5% by volume of acetone is to be freed of its acetone content by scrubbing it with water in a packed bed absorber. The flow rate of the gas mixture is 700 m^3/h of acetone-free air measured at N.T.P., and that of water is 1500 kg/h. The absorber operates at an average temperature of $20^\circ C$ and a pressure of 101 kPa.

The scrubber is 98% of acetone.

The equilibrium relationship for acetone vapour-water system is given by $Y^* = 1{\cdot}68X$

where Y = k mole acetone/k mole dry air

and X = k mole acetone/k mole water

Calculate the mean driving force for absorption and the mass transfer area if the overall mass transfer coefficient is K_G = 0·4 k mole acetone/m^2h (k mole acetone/k mole dry air). 8 + 7

10. Derive 'Kremser equation' for a plate type absorption column, stating all the assumptions.

11. State basic assumptions for Langmuir type adsorption. Derive mathematical expression for Langmuir isotherm. Discuss the graphical method of determining usual parameters of the isotherm. 3 + 7 + 5

12. a) Discuss the Penetration Theory in brief.

b) A test tube, 1·5 cm in diameter and 12 cm tall, is partly filled with a solution of alkaline pyrogallate. The depth of the empty space above the solution is 5 cm. The temperature is 25°C and the total pressure is 1 atmosphere. Air may be assumed to contain 21% O_2 and 79% N_2. The diffusivity of O_2 in N_2 at the given condition is 0·21 cm^2/s.

i) Calculate the rate of absorption of oxygen from air in the solution at steady state if air flows gently over the open end of the test tube.

ii) Calculate the flux of the component midway of the diffusion path with respect to an observer moving with double the molar average velocity at the location in the direction away from the liquid surface. 5 + (5 + 5)

13. A liquid mixture of benzene-toluene is to be distilled in a fractionating tower at 101·3 kPa pressure. The feed of 100 k-mol/h is liquid, containing 45 mol% benzene and 55 mol% toluene, and enters at 327·6 K. A distillate containing 95 mol% benzene and 5 mol% toluene and a bottoms containing 10 mol% benzene and 90 mol% toluene are to be obtained. The reflux ratio is 4. The average heat capacity of the feed is 159 kJ/k mol. K and the average latent heat 32,099 kJ/k mol. Calculate the k moles per hour distillate, k moles per hour bottoms and the number of theoretical trays needed.

Equilibrium data for the system is given below :

x_A	1·000	0·780	0·581	0.411	0·258	0·130	0
y_A	1·000	0·900	0·777	0.632	0·4556	0·261	0

Data : Boiling point of the feed (TB) = 366·7 K

Inlet feed temperature (TF) = 327·6 K