CS/B.TECH (CHE)-OLD/SEM-5/CHE-505/2012-13

2012

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) Penetration theory relates average mass transfer coefficient (K) with diffusivity (D) as

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

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

ii) NTU is numerically equal to Number of Theoretical plates only when operating line

a)   lies below the equilibrium curve

b)   lies above the equilibrium curve

c)   and the equilibrium lines are straight and parallel

d)   is far from the equilibrium line.

iii) In physical terms, Schmidt number means

    a)   thermal diffusivity / mass diffusivity

    b)   Thermal diffusivity / momentum diffusivity

    c)   Momentum diffusivity / mass diffusivity

    d)   Mass diffusivity / thermal diffusivity.

iv) Rayleigh equation applies to

    a)   differential distillation

    b)   flash distillation

    c)   azeotropic distillation

    d)   molecular distillation.

v) Steam distillation is used to separate

    a)   azeotropes

    b)   high boiling substances from non-volatile impurities

    c)   heat sensitive materials

    d)   mixtures of low relative volatility.

vi) Fenske equation determines

    a)   maximum number of ideal plates

    b)   height of the distillation column

    c)   minimum number of theoretical plates

    d)   optimum reflux ratio.

vii) A feed mixture for distillation contains 25% liquid and rest is vapour. q value of the mixture is

    a)   3   b)   0

    c) $\dfrac{1}{4}$ d) $\dfrac{3}{4}$.

viii) The operating line for an absorber is curved when plotted in terms of

   a) mole fractions   b) mole ratios

   c) partial pressure   d) mass fractions.

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

   a) 0   b) 1

   c) < 1   d) ∞.

x) Entropy change for adsorption is

   a) negative   b) zero

   c) positive   d) not predictable.

xi) The length of the unused bed (LUB) is more if the mass transfer zone is

   a) wide   b) narrow

   c) asymmetric   d) symmetric.

xii) A column receives a 'cold reflux', and the 'external reflux ratio' is 2·0. For each mole of the cold reflux, 0·05 mole of the vapour condenses at the top tray. What is the true slope of the rectifying section operating line ?

   a) 0·677   b) 0·5

   c) 1·0   d) 0·0.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 15$

2. Prove that for equimolar counter-diffusion from a sphere to a surrounding stationary infinite medium, the Sherwood number based on the dimeter of the sphere is equal to 2.

3. How is the height of overall gas phase transfer unit H_{OG} related to the height of gas film transfer unit H_G and the height of liquid film transfer unit H_L if the equilibrium relationship is given by $y^* = mx$ and gas flow rate and liquid flow rates are given by G_m and L_m ?

4. Calculate the time required for the sublimation of 3 kg of naphthalene from a naphthalene ball of mass 4 kg kept suspended in a large volume of stagnant air at 45°C and 1·013 bar pressure. Diffusivity of naphthalene in air under the given conditions is 6.92×10^{-6} m^2/sec, its density is 1140 kg/m^3, its sublimation pressure at 45°C is 0·8654 mm Hg and molecular weight of naphthalene is 128 kg/kmol.

5. A batch of crude pentane contains 15 mol% *n*-butane and 85% *n*-heptane. If a sample batch distillation at atmospheric pressure is used to remove 90% of the butane, how much pentane will be removed ? What will be the composition of the remaining liquid ? Average relative volatility of butane-pentane mixture may be taken as 3·5.

6. Air separation is done by liquefaction followed by cryogenic distillation or it is done by PSA. Which technique allows a higher turndown ratio and why ?

GROUP – C

(Long Answer Type Questions)

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

7. a) Hydrochloric acid is diffusing across an inert air film 0·2 cm thick at a temp of 20°C and 1 atm total pressure. Estimate the effect on the rate of diffusion on raising the pressure to 10 atm. If the concentration of hydrochloric acid is (a) 0·1 atm and (b) 10% by volume on one boundary of the film, at the other boundary the pressure is zero for both the cases. The diffusivity for the system is 521·186 cm^2/hr at 20°C and 1 atm pressure.

   b) Define the terms HTU, NTU and HETP.   12 + 3

8. a) In distillation, what is meant by q ? State with a neat diagram the values / range of values of q and nature of different q-lines for different feed conditions.

   b) It is proposed to absorb ethanol vapour from air-ethanol mixture using water as a solvent in a packed absorption column at 40°C and 1 atm pressure. Inlet gas flow rate is 500 m^3/hr with ethanol composition being 5 vol %. It is required to absorb 95% of ethanol vapour by absorption. The diameter of the column is 3 m. Determine the height of the packed column required for pure water flow rate 1·5 times the minimum. Given $H_G = 0·3$ m, $H_L = 0·2$ m and equilibrium relation is given by $y = 1·0682\ x$.   5 + 10
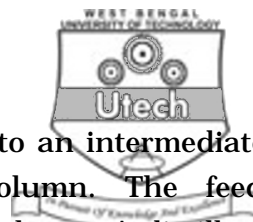
9. A mixture of Benzene and Toluene is fed to an intermediate point of a continuous fractionating column. The feed contains 45 mol% Benzene and 55 mol% Toluene. A distillate containing 92 mol% Benzene and 8 mol% Toluene is obtained. The bottoms contain 15 mol% Benzene and 85 mol% Toluene. One mol of distillate product is removed for every 4 mol returned to the unit as reflux. The feed enters at 55°C and the unit operates at atmospheric pressure. Calculate

   i) Minimum reflux ratio

   ii) Theoretical number of stages required under these conditions

   iii) Locate the feed tray.

   It is known that the molal heat capacity of liquid mixture of Benzene and Toluene in all proportions may be taken as 40 cal/gmol°C. The molar heat of vaporization of Benzene and Toluene may be taken as 7612 cal/gmol.

   The normal boiling point of a mixture containing 0·45 mol fraction Benzene and 0·55 mol fraction Toluene is 98·8°C.

   The equilibrium data :

x :	0·1	0·2	0·3	0·4	0·5	0·8
y :	0·2	0·37	0·51	0·62	0·78	0·9

10. The following is the experimental breakthrough data for adsorption of vinyl chloride on granular activated carbon at 20°C and essentially atmospheric pressure.

Time, t (min)	141	154	166·7	205	246	282	318	350
y/y_i	0	0	0·018	0·223	0·587	0·807	0·966	1·0

Details of the experimental parameters for an adsorption experiment are : bed length, $L = 15 \cdot 2$ cm ; bed diameter, $d = 2 \cdot 3$ cm ; gas flow rate = 80 cm^3/s at 1 atm and 20°C ; bed porosity, $\varepsilon = 0 \cdot 36$; interstitial gas velocity = $0 \cdot 535$ m/s; vinyl chloride concentration in the feed = 190 ppm (by volume) y_i = mole fraction of the solute in the feed gas and y is that in the effluent.

a) Calculate the length of the mass transfer zone, the velocity of the stoichiometric front and the saturation capacity of the bed at the influent gas concentration.

b) A waste gas stream containing 190 ppm (by volume) vinyl chloride is to be treated with activated carbon in a packed bed at a rate of 20 m^3/min to reduce its concentration by 98%. Using the above breakthrough data, determine the bed diameter, the height and pressure drop if an adsorption period of 10 h is allowed. The superficial gas velocity to be used is the same as that of the experimental study.   7 + 8

11. Write short notes on the following :

    i)   Penetration theory

    ii)   Tray efficiencies in plate column

    iii) Rayleigh equation

    iv)   Steam distillation.

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