Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech (FT) (N)/SEM-5/CHE-514/2012-13

2012

UNIT OPERATION OF CHEMICAL ENGINEERING-II

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) It is proposed to purify benzene from a small volume of non-volatile solutes by subjecting it to distillation with saturated steam under atmospheric pressure of 745 mm of Hg. Calculate the temperature at which the distillation will proceed :

	Temp. (°C)	VP of water in mm Hg	VP of benzene in mm Hg
(a)	60	150	390
(b)	65	190	460
(c)	68	215	510
(d)	69	225	520

ii) At the time of total reflux, the equation for the stripping section operating line is given by

a) $y_{n+1} = \{R/(R+1)\}\, X_n + \{X_d/(R+1)\}$

b) Operating line for both sections is a 45° diagonal line

c) Equations of operating line of rectification section and feed line are identical

d) There should be no operating line.

iii) For a liquid mixture of two components at a given temperature and pressure, the relative volatility is defined as

a) $\alpha = (y_i/x_i)/(y_j/x_j) = K_i/K_j$

b) x_i / x_j

c) y_i / y_j

d) $(x_i/x_j)/(y_i/y_j)$.

iv) Boiling point diagram is

a) not affected by pressure

b) affected by pressure

c) a plot of temperature *vs* liquid composition

d) a plot of temperature *vs* vapour composition.

v) In azeotropic mixture, the equilibrium vapour composition is

a) more than liquid composition

b) less than liquid composition

c) same as liquid composition

d) independent of pressure.

vi) In steam distillation, the

a) temperature is 100 °C

b) temperature is more than 100 °C

c) product must be immiscible with water

d) temperature is higher than the boiling point of either component.

vii) Which one of the following is an absorption type mass transfer operation ?

a) Separation of air-ammonia mixture by direct contact with water

b) Separation of water-ammonia mixture by direct air contact

c) Separation of gas mixture of propane & propylene by direct contact with activated C

d) Separation of acetone water in separating funnel with CCl_4.

viii) For the case of cracking reaction $CH_4 \longrightarrow C + 2H_2$, CH_4 (A) diffuses to the cracking surface and H_2 diffuses back. If the fluxes are NA and NB respectively then NA/NA + NB equals to

a) 0 b) 1

c) –1 d) 1/2.

ix) In dialysis permeability is

a) directly proportional to the thickness of the membrane

b) inversely proportional to the thickness of the membrane

c) equal to the thickness of the membrane

d) none of these.

x) Water activity is 1·0

a) at critical moisture content

b) above critical moisture content

c) below critical moisture content

d) wet sample to critical point.

xi) The unit of specific cake resistance is

a) m^{-1} b) $m.kg^{-1}$

c) m d) $kg.m^{-1}$.

xii) The number of stages in cocurrent extraction process is

a) $n = [\log (X_f/X_n)/\log \{A/(A + Sm)\}]$

b) $n = [\log (X_f/X_n)/\log \{(A + Sm)/A\}]$

c) $n = [\log (X_n/X_f)/\log \{A/(A + Sm)\}]$

d) $n = [\log (X_n/X_f)/\log \{(A + Sm)\, A\}]$.

xiii) 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) $D \propto T^{2}$.

xiv) Schmidt number is

a) μ/D_{AB} b) Re. Pe

c) Sh. Pe d) Re/Pe.

xv) Drying of a solid involves

a) only heat transfer

b) only mass transfer

c) both heat and mass transfer

d) none of these.

xvi) Rate of leaching increases with increasing

a) temperature

b) viscosity of solvent

c) pressure

d) size of solid.

GROUP – B

(Short Answer Type Questions)

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

2. Deduce Rayleigh equation for batch distillation process.
3. A continuous fractionating column has to be designed to separate 30000 kg/h of a mixture of 40 % benzene and 60 % toluene into an overhead product containing 97 % benzene and a bottom product containing 98 % toluene. The % is by weight basis. Calculate the moles of overhead and bottom products.

4. Explain the mechanism of crystallization process in respect of crystallization and grain growth.
5. Derive the expression for overall mass transfer coefficient when the system is liquid film controlling.
6. Explain briefly the operating principle of a Rotary Drier.
7. Define diffusivity. CH_4 diffuses at steady state through a tube containing He. At point 1 the partial pressure of CH_4 is p_A = 55 kPa & at point 2, 0·03 m apart p_A = 15 kPa. The total pressure is 101·32 kPa & temperature 298 K. At this temperature & pressure the value of diffusivity is $6{\cdot}75 \times 10^{-5}$ m^2/s. Calculate the flux of CH_4 at steady state for equimolar counter diffusion. 2 + 3

GROUP – C

(Long Answer Type Questions)

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

8. a) 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 gas mixture is 700 m^3 /h of acetone free water measured at N.T.P and that of water is 1500 kg/h. The absorber operates at an average temperature of 20°C and pressure 101 kPa. The scrubber absorbs 98 % of acetone.

The equilibrium relationship for acetone vapour-water system is given by

$Y^* = 1{\cdot}68\ X$

where Y = kmol of acetone/kg mol of acetone-free air

X = kg mol of acetone per kg mol of acetone-free water.

Calculate the mean driving for absorption and mass transfer area if the overall mass transfer coefficient $K_G = 0 \cdot 4$ kmol of acetone/ m^2h.

b) Calculate the rate of diffusion of carbon dioxide CO_2 through a membrane of vulcanized rubber 1 mm thick at $25^\circ C$, if the partial pressure of CO_2 is 1 mm Hg on one side and 0 on the other. Calculate also the permeability of the membrane for CO_2 at $25^\circ C$. The solubility coefficient is 0·90 cm^3 gas at STP/ cm^3 . atm.

10 + 5

9. a) Show that for binary gas mixture, the diffusivity of A in B equals to the diffusivity of B in A.

b) A liquid mixture of benzene-toluene is to be distilled in a fractionating tower at 101·3 kPa. The feed of 100 kg-mol/hr is liquid, containing 45 mol% benzene and 55 mol % toluene and enters at 321·6°C. A distillate contains 95 mol% benzene and 5 mol% toluene and the

bottom product contains 10 mol% benzene and 90 mol% of toluene. The reflux ratio is 4 : 1. The average heat capacity of feed is 159 kJ/kg-mol-K and the average latent heat is 32099 kJ/kg-mol. The equilibrium data of benzene and tolune are given below :

X	1·000	0·780	0·581	0·411	0·258	0·130	0·000
Y	1·000	0·900	0·777	0·632	0·456	0·261	0·000

Calculate the kg-mol per hour of distillate, kg-mol per hour of bottom and the no. of theoretical trays needed.

5 + 10

10. a) A hollow fibre permeator with $d_0 = 300\ \mu m$ and $d_i = 200\ \mu m$ gives a water flux of $4{\cdot}72 \times 10^{-6}$ m/s with 0·1 M NaCl solution at 20°C, and the salt rejection is 97 per cent. Feed solution flows normal to the fibre at an average superficial velocity of 5×10^{-3} m/s. Is concentration polarization significant ? Estimate the exit velocity and the pressure drop within the fibre if the fibre length is 3m based on the external area. What is the pressure drop if the fibres are open at both ends ? Assume $\mu = 10^{-3}$ Pa.s and $D_s = 1 \cdot 6 \times 10^{-9}$ m^2/s.

b) What is concentration polarization of a membrane ? What is membrane fouling ? How is it controlled ?

10 + 5

11. a) A wet solid is dried from 25 % to 10 % moisture under constant drying conditions in 4·17h. If the critical and the equilibrium moisture contents are 15 % and 5 % respectively, how long will it take to dry the solid from 30 % to 8 % moisture under the same conditions ?

b) Write the basic principle of spray drying operation.

c) Write a brief note on choice of solvent in case of liquid-liquid extraction. 5 + 5 + 5

12. a) What is murphree plate efficiency of a distillation column ?

b) Define H.E.T.P. and H.T.U. of a distillation column.

c) A liquid feed at its boiling point of 400 kg-mol/h containing 70 mol % of benzene (A), 30 mol % of toluene (B) and fed to a stripping tower at 101·3 kPa pressure. The bottom product flow is to be 60 kg-mol/h containing only 10 mol % of A and rest B. Calculate the kg-mol/h of overhead product, its composition and number of theoretical trays required. The equilibrium data of benzene-toluene system is given below :

X	1·000	0·700	0·581	0·411	0·258	0·130	0
Y	1·000	0·900	0·777	0·632	0·456	0·261	0

2 + 3 + 10

13. Discuss what you mean by

    a) Membrane fouling

    b) Steam distillation

    c) Spray drier ?

14. a) What do you understand by inter-phase mass transfer ?

    b) Derive an expression for the height of a packed absorption tower based on the condition of liquid film.

    c) Derive the relation between overall and individual mass transfer co-efficient. 3 + 5 + 7

15. Derive the equation for the operating line of the rectifying section of a distillation column. Discuss the method of calculation of number of theoretical plates and location of feed plate by McCabe-Thiele method. 7 + 8

16. Write short notes on any *three* of the following : 3 × 5

    a) Azeotropic distillation

    b) Liquid-liquid extraction

c) Rayleigh's equation

d) Pervaporation

e) Drum drying process

f) Crystallization.