



Comprehensive Examination

PART – A (Close Book)

Marks: 40

Date: 03/05/18

Time: 60 minutes

**Note: Close book question paper consists of 10 Short Questions (4 Marks each). Write the final answers in the space provided at the end of question paper.**

1. In a distillation operation, the feed is a saturated liquid with 50 mole% more volatile component A. The distillate is with 75 mole%, what is the **minimum reflux ratio** with relative volatility as 2?
2. For steady state molecular diffusion of gas A through non-diffusing B, the **ratio  $N_A/(N_A+N_B)$**  is \_\_\_\_\_.
3. A binary distillation column is designed by McCabe-Thiele method to get a distillate mole fraction of 0.9. The enriching section operating line has an intercept with y-axis at 0.3 mole fraction. **The ratio of liquid to vapor molar flow rate in the enriching section** is \_\_\_\_\_.
4. Air concentrated with solute P is brought in contact with water. At steady state, the bulk concentration of P in air and water are 0.3 and 0.02 respectively. The equilibrium equation relating the interface compositions is  $y_{P,i} = 0.25 x_{P,i}$ . Assume that the mass transfer coefficient  $k_G$  and  $k_L$  are identical. Calculate the gas phase mole fraction of P at the interface ( $y_{P,i}$ ).
5. Crushed oil seeds containing 55% oil by weight is to be extracted at the rate of 4060 kg/h using 100 kg/min of n-hexane containing 5% oil by weight as solvent. A counter current single stage extraction system is employed. The oil seeds will retain 1 kg of solution per kg of oil-free cake. **Estimate the composition of oil in overflow solution** under the above conditions.
6. In industries titanium is hardened through diffusion of carbon. The concentration of carbon at 1 mm into the surface of the titanium slab is 0.25 kg/m<sup>3</sup> and at 3 mm the concentration is 0.68 kg/m<sup>3</sup>. The rate at which the carbon is entering into its surface is  $1.27 \times 10^{-9}$  kg/m<sup>2</sup>.s. **Calculate the value of diffusion coefficient of carbon in m<sup>2</sup>/s.**
7. Given for an absorber, the minimum non-diffusing liquid flow rate is 20 moles/hr and the non-diffusing gas flow rate is 30 moles/hr. As the actual liquid flow rate is 2.5 times the minimum. **Find the slope of operating line.**
8. **Find the separation factor**, if the ratio of weight fraction of solute in extract to raffinate is 0.75 and the ratio of dilutant in raffinate to extract is 0.5.
9. An aqueous solution containing 1.5 kmol X/m<sup>3</sup> is fed at 36 ml/s to the top of extraction column of height 1.60 m and cross sectional area of 0.0045 m<sup>2</sup> and it leaves at the bottom with 1.4 kmol X/m<sup>3</sup>. An organic solvent, B, containing 0.008 kmol X/m<sup>3</sup> flows counter currently to the aqueous phase at 9 ml/s. The equilibrium relationship is  $C_{x,organic} \text{ (kmol X/m}^3\text{)} = 0.3 C_{x,aqueous} \text{ (kmol/m}^3\text{)}$ . The concentration of X in organic phase leaving from top of the extraction column is \_\_\_\_\_ kmol X/m<sup>3</sup>.
10. In a typical chemical process, component A is desorbed from an aqueous solution into an air stream in a mass transfer tower at a certain operating temperature and pressure. At a particular point in the tower, analysis report shows the bulk gas phase and liquid phase concentration are 14 mm Hg and 4 kmole/m<sup>3</sup> respectively. The overall mass transfer coefficient,  $K_G = 0.269$  kmole A/(m<sup>2</sup>.h.atm). If the Henry's law is applicable to this system and if 60% of the total mass transfer resistance is encountered in gas film. **Calculate the gas film coefficient in kmole A/(m<sup>2</sup>.h.atm) and molar flux of component A in kmole/(m<sup>2</sup>.h).** Data: Henry's law constant =  $7.5 \times 10^{-3}$  (atm. m<sup>3</sup> solution)/mole A.



**Course Title: Separation Process I (CHE F244)**  
**Comprehensive Examination**  
**PART – A (Close Book)**  
**Answer Sheet**

<b>Name:</b>	<b>ID No.:</b>
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**Answers for Short Questions: (Part –I)**

<b>Q. No.</b>	<b>Answer</b>	<b>Q. No.</b>	<b>Answer</b>
<b>1.</b>	<b>0.506</b>	<b>6.</b>	<b><math>5.907 \times 10^{-12}</math></b>
<b>2.</b>	<b>1</b>	<b>7.</b>	<b>1.667</b>
<b>3.</b>	<b>2/3 or 0.667</b>	<b>8.</b>	<b>0.375</b>
<b>4.</b>	<b>0.064</b>	<b>9.</b>	<b>0.408</b>
<b>5.</b>	<b>0.3076 or 30.76%</b>	<b>10.</b>	<b>0.4483 and <math>3.115 \times 10^{-3}</math></b>
<b>Total Marks</b>			

**BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI, PILANI CAMPUS**  
**CHEMICAL ENGINEERING DEPARTMENT**  
**Course Title: Separation Process I (CHE F244)**  
**Comprehensive Examination (PART –B)**

**OPEN-BOOK**

**Marks: 80**

**Date: 03/05/18**

**Time: 120 minutes**

**1. (20 Marks)**

A packed column is used to remove ammonia from the gas purged from an ammonia plant in order to reduce the effluent to 0.10 mole% NH<sub>3</sub>. The gas to be treated contains 2.0 mole% NH<sub>3</sub>, 32 mole% nitrogen and 66 mole% hydrogen. It will be scrubbed with pure water in a counter-current absorber packed with 25 mm Berl saddles using an inlet gas flow rate of 1.13 kg/m<sup>2</sup>.s and a pure water flow rate of 1.6 times the minimum value. Assume isothermal operation at 293 K and 1 atm, since heat of solution and cooling due to water evaporation offset each other at this NH<sub>3</sub> concentration. Equilibrium can be approximated to  $y^* = x$  under these conditions. Neglect small absorption of nitrogen and hydrogen. The value overall gas phase mass transfer coefficient is  $7.9 \times 10^{-4}$  mol/m<sup>3</sup> s Pa. **Assume dilute system** and Find:

- How many equilibrium stages (theoretical plates) are required using **Kremser equation**?
- How many overall transfer units,  $N_{OG}$  is required?
- How many meters of packing are required?

**2. (20 Marks)**

Roasted copper ore containing the copper as CuSO<sub>4</sub> is to be extracted in a counter-current stage extractor. Each hour a charge consisting of 5000 kg of inert solids, 1200 kg of copper sulfate and 400 kg of water is to be treated. The strong solution (overflow) produced is to consist of 40% by weight of copper sulfate. The recovery of copper sulfate is to be 95% of that in the ore. Pure water is to be used as solvent. After each stage, 1 kg of inert solids retain 0.5 kg of water plus the CuSO<sub>4</sub> dissolved in that water. Equilibrium is attained in each stage. Calculate the underflow and overflow mass flow rates, solvent mass flow rates, and no. of equilibrium stages required for desired separation.

**3. (20 Marks)**

A fractionating column separates a liquid mixture of 50 wt% chloroform (CHCl<sub>3</sub>) and 50 wt% CS<sub>2</sub> at 1 atm at the rate of 5000 kg/hr into a distillate containing 94 wt% CS<sub>2</sub> and a residue of 96 wt% chloroform. The feed is 50 mol% vapor before entering the tower. A total condenser and reflux at its bubble point are used. The equilibrium data are as follows:

$x$	0	0.03	0.06	0.11	0.14	0.26	0.39	0.53	0.66	0.76	0.86	1.0
$y$	0	0.08	0.16	0.27	0.33	0.5	0.63	0.735	0.83	0.88	0.93	1.0

$x$  and  $y$  refer to the mole fraction of CS<sub>2</sub> in the liquid and vapor respectively.

Calculate the following:

- Mass flow rates of top and bottom products in kmol/hr.
- Minimum reflux ratio.
- Minimum number of stages at total reflux
- Number of stages at reflux ratio of 2.2 times the minimum
- Composition of liquid and vapor leaving the second plate from top.

**4. (20 Marks)**

The system docosane- diphenylhexane (DPH)- furfural is representative of more complex systems encountered in the solvent refining of lubricating oil. 500 kg/h of a 40 wt% mixture of DPH in docosane are to be continuously extracted in a countercurrent system with 600 kg/h of a solvent containing 98 wt% furfural and 2 wt% DPH to produce a raffinate that contains only 5 wt% DPH. Calculate the following with right-angle diagram:

- (a) Weight percent of DPH and furfural in extract stream.
- (b) The flow rates of exiting extract and raffinate streams.
- (c) No. of equilibrium contact needed.

**Data:**

<b>Composition data (wt%)</b>		
<b>Docosane</b>	<b>DPH</b>	<b>Furfural</b>
96.0	0	4.0
84.0	11.0	5.0
67.0	26.0	7.0
52.5	37.5	10.0
32.6	47.4	20.0
21.3	48.7	30.0
13.2	46.8	40.0
7.7	42.3	50.0
4.4	35.6	60.0
2.6	27.4	70.0
1.5	18.5	80.0
1.0	9.0	90.0
0.7	0.0	99.3

**The tie line in the docosane-DPH-furfural are:**

<b>Docosane phase composition, wt%</b>			<b>Furfural phase composition, wt%</b>		
<b>Docosane</b>	<b>DPH</b>	<b>Furfural</b>	<b>Docosane</b>	<b>DPH</b>	<b>Furfural</b>
85.2	10.0	4.8	1.1	9.9	89.0
69.0	24.5	6.5	2.2	24.4	73.4
43.9	42.6	13.3	6.8	42.1	51.1