Closed Book

Birla Institute of Technology & Science, Pilani

Pilani Campus

I Semester / II Semester / Summer Term 20___- 20___

Comprehensive Examination (Regular/Make-Up)

ID No. _____ Name _____

Course No. _____ Course Title _____Section No._____

Instructor's Name _____ Room No. _____ Date_____

Verified:
Signature of Invigilator:

INSTRUCTIONS

1. Enter all the required details on the cover of every answer booklet.
2. Write on both sides of the sheet in the answer book. Rough work, if any should be done at the bottom of the page. Finally cross out the rough work and draw a horizontal line to separate it from the rest of the material on the page. Also, cross out all blank pages in the answer booklet.
3. Any answer crossed out by the student will not be examined by the examiner.
4. No sheet should be torn from the answer booklet.
5. Mobile phones or any electronic communication/storage device of any kind is prohibited in the examination hall.
6. Use of any unfair means will make the candidate liable to disciplinary action.
7. Student should not leave the examination hall without submitting the answer booklet to invigilator on duty.
8. Student must abide by all the instructions given by the invigilator(s) on duty.

I have carefully read and understood all the instructions.

I do understand that any attempt to use unfair means of any kind in an examination is a serious and punishable offence.

I hereby declare that I will not attempt to do any malpractice in the examination.

Signature of the student

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
Department of Chemical Engineering
Second Semester 2022-2023
Comprehensive Examination (Closed Book)
CHE F244: SEPATATION PROCESSES-I

DATE: 20.05.2023 **Maximum Marks: 120**

***Note*:** The question paper consists of two parts. **Part A** is of 30 marks and of 60 minutes duration. **Part B** question paper can be collected only after submission of Part A answer sheet.

Time: 1 hour **PART – A** **Marks: 30**

Write your answers on the Answer Sheet provided in Page 3. Rough work can be done in the main answer book. Only the final answer will be evaluated.

1. What are the values of the heat transfer coefficient h (in $W/m^2.^oC$) and thermal conductivity k (in $W/m.^oC$) for a system where, mass transfer coefficient $k_L = 4.55x10^{-8}$ m/s, Lewis number Le = 1974, diffusivity $D_{AB} = 1.21 \times 10^{-9}$ m^2/s, density $\rho = 997$ kg/m^3 and specific heat $C_p = 4.2$ $kJ/kg.^oC$?
2. What is the diffusivity D_{AB} (in cm^2/s) for O_2–C_6H_6 system at 1 atm, 25°C? Given $M_A = 32$, $M_B = 78$, $\sum v_A = 16.3$, and $\sum v_B = 90.96$. Use F-S-G equation.
3. What is the Murphree tray efficiency in an absorption column if G_s= 90 kmol/h, L_s = 100 kmol/h, $y_{n+1} = 0.12$, $x_n = 0.078$, $x_{n-1} = 0.06$, and $Y^* = 1.01$ X.
4. What will be the composition of the vapor and liquid in the separator when a 60 mol% vaporized liquid mixture ($\alpha = 2.5$) containing 50 mol% A and 50 mol% B is continuously flash vaporized at 1 std atm? (No graph required. Solve analytically.)
5. What is the height of one transfer unit when 1200 $kg/hr.m^2$ of NH_3-Air mixture containing 5 % ammonia by volume is absorbed in water in a packed column operated at 20°C and 1 atm pressure if overall mass transfer coefficient is 1 $kmol/h.m^2.atm$ and interfacial area of packing materials is 190 m^2/m^3?
6. 100 kmol/h of SO_2-Air mixture containing 5% by volume of SO_2 is scrubbed with 7000 kmol/h of water in a packed tower. What is the NTU for 97% recovery of SO_2 if equilibrium relation is $Y^* = 0.30$ X, where X and Y are corresponding mole ratios?
7. A mixture of benzene (A) and toluene (B) containing 40 mol% benzene is to be separated continuously in a tray tower at a rate of 200 kmol/h. The top product should have 94 mol% benzene and the bottom must not contain more than 4 mol% of it. The reflux is saturated liquid and a reflux ratio of 2.0 is maintained. For a 60% vaporized feed, obtain the followings:
   a) Distillate and bottoms flow rates in kmol/h.
   b) Latent heat of vaporization at the top and bottom if λ_A =30,770 kJ/kmol and λ_B = 32,120 kJ/kmol.
   c) Vapor rates in kmol/h at the rectifying and stripping sections.
   d) Equations of operating lines in the rectifying and stripping sections.
   e) Condenser and reboiler heat duties in kW for constant molar overflow.
   f) Volumetric vapor flow rates at the top and bottom in m^3/h assuming boiling points of benzene and toluene to be78°C and 100°C at 1 atm pressure.

[Q1 to Q6: 3 marks each; Q7a to Q7f: 2 marks each]

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ANSWER SHEET (PART-A)

Question No.	Answer	
1	**h =**	**k =**
2	**D_{AB} =**	
3	**E_{MG} =**	
4	**x_w =**	**y_D^* =**
5	**HTU =**	
6	**NTU =**	
7a	**D =**	**W =**
7b	**λ_{top}=**	**λ_{bottom}=**
7c	**V =**	$\bar{V} =$
7d	**y_{n+1} =**	**y_{m+1} =**
7e	**Q_C =**	**Q_B =**
7f	$\dot{v}_{top} =$	$\dot{v}_{bottom} =$

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
Department of Chemical Engineering
Second Semester 2022-2023
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CHE F244: SEPATATION PROCESSES-I

Date: 20.05.2023 **Maximum Marks: 120**

Time: 2 hours **PART – B** **Marks: 90**

1. (30 *Marks*)
A distillation column receives two feeds: (i) 200 kmol/h, 80% liquid and 20% vapor, with 42.86 mole% methanol and rest water; (ii) 100 kmol/h, saturated liquid, with 17.65 mole% methanol and rest water. The top product must have a purity of 96.1 mole% and the bottoms must not have more than 3.1 mole% of the alcohol. A liquid side stream having 66.67 mole% methanol is to be withdrawn at a rate of 35 kmol/h. The reflux is returned to the top tray as a saturated liquid at a reflux ratio of 2.0. (a) Find the number of ideal trays required for the separation. (b) Identify the feed trays and also the tray from which the side stream should be withdrawn. Vapor-liquid equilibrium data at the operating pressure of 1 atm is as follows:

x	0	0.02	0.04	0.06	0.08	0.10	0.20	0.30	0.40
y*	0	0.134	0.23	0.304	0.365	0.418	0.579	0.665	0.729
x	0.50	0.60	0.70	0.80	0.90	0.95	1.0		
y*	0.779	0.825	0.87	0.915	0.958	0.979	1.0		

Hint: Take scale: 2 cm = 0.1 on both axes.

2. (20 *Marks*)
One thousand kilogram per hour of a 45 wt% acetone in water solution is to be extracted at 25^{o}C in a continuous counter-current system with pure 1,1,2-trichloroethane (TCE) to obtain a raffinate containing 5 wt% acetone. Determine the number of ideal stages for a solvent rate equal to 1.38 times the feed rate. The compositions of the raffinate and the extract as well as the tie-line data are given below (water: A; TCE: B; Acetone:C):

Raffinate layer	x_B	0.10	0.07	0.03	0.02	0.01	0.005	0.001
	x_C	0.55	0.50	0.40	0.30	0.20	0.10	0.01
Extract layer	y_B	0.27	0.46	0.57	0.68	0.785	0.89	0.98
	y_C	0.60	0.50	0.40	0.30	0.20	0.10	0.01

Tie-line data	x_C	0	0.44	0.29	0.21	0.12	0.05
	y_C	0	0.56	0.40	0.30	0.18	0.08

Hint: Take scale, for solute axis (x-axis): 3 cm = 0.1, for solvent axis (y-axis): 1 cm = 0.1

3. (20 *Marks*)
One thousand kilograms of crushed oil seeds containing 20 wt% oil (C) and the balance insoluble meal (A) is to be extracted three times with pure hexane (B) in a cross-current system using 500 kg hexane in each stage. It is observed that the underflow from each stage contains 0.67 kg solution per kg of insoluble meal. Calculate the percentage of oil that can be extracted (recovered).

Hint: Take scale, for solute axis (x-axis): 1 cm = 0.01, for solvent axis (y-axis): 1 cm = 0.1

4. (20 *Marks*)

(a) Explain why the section above the feed tray in a distillation column is called as rectifying section or enriching section.
(b) Explain what happens to the less volatile component in the liquid stream as it goes down in the stripping section.
(c) Explain why the hypotenuse represents the overflow locus in leaching when right-angled ternary plot is used.
(d) Explain the significance of plait point and binodal curve (phase envelope) in liquid-liquid extraction.
(e) Explain how can you obtain the real number of stages and real feed tray using McCabe-Thiele method if Murphree vapor efficiencies are given at different liquid mole fraction of more volatile component.

~ All the Best ~