NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

MASS TRANSFER PROCESSES 1B

TCE 2203/ECE 2201

Final Examination Paper

March 2025

This examination paper consists of 4 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Graph paper

INSTRUCTIONS

1. Answer **ALL** questions in Section A and **ANY TWO** questions from Section B.
2. Each question carries 25 marks.
3. Use of calculators is permissible.
4. Start the answers for each question on a new page.
5. If graph paper is used, make sure the graph occupies at least three quarters of an A4 size sheet.

MARK ALLOCATION

QUESTION	MARKS
A1.	**25**
A2.	**25**
B1.	**25**
B2.	**25**
B3.	**25**
TOTAL ATTAINABLE	**100**

SECTION A
Answer all questions from this section

QUESTION A1

a) Citing two relevant practical applications of each, state and explain any five separation processes commonly used in the chemical industry. **[10]**

b) One separation stage is rarely sufficient to produce commercial products of acceptable quality. Cascades, which are aggregates of stages, are needed to accomplish separations that cannot be achieved in a single stage. With the aid of diagrams. explain the three possible cascade configurations or stage arrangements that can be used to accomplish improved separation in the chemical industries. **[6]**

c) For specified feed and desired products, the selection of a feasible mass transfer operation is influenced by factors such as feed conditions, product specifications, property differences that may be exploited, as well as economic and environmental considerations. For any three of the five mentioned factors, explain two important parameters that will dictate the selection of a separation process. **[9]**

QUESTION A2

a) Gas absorption, leaching, and liquid-liquid extraction are mass transfer unit operations that are widely used in the chemical industries. The efficiency of each of the stated processes is influenced by the solvent used. Briefly explain any five factors taken into consideration when selecting solvents for mass transfer operations. **[10]**

b) Drying is the removal of moisture (either water or other volatile compounds) from solids, solutions, slurries, and pastes to give solid products. Various types of dryers exist for the removal of moisture and these can be classified in a number of ways. State any three methods of classifying dryers giving two examples of dryers that fall in each class. **[9]**

c) Differentiate liquid-liquid extraction from distillation and explain any three situations under which liquid-liquid extraction might be preferred to distillation. **[6]**

SECTION B

Answer any two questions from this section

QUESTION B1

a) In a bioprocess, molasses is fermented to produce a liquor containing ethyl alcohol. A CO_2-rich vapor with a small amount of ethyl alcohol is evolved. The alcohol is recovered by absorption with water in a sieve-tray tower. Gas enters at 900 m^3/h; 98% CO_2, 2% ethyl alcohol; 30°C and 110 kPa. The liquid absorbent enters at 99.5% water; 0.5% ethyl alcohol, 30°C and 110 kPa. The required recovery of ethyl alcohol is 95% and the vapor pressure of ethyl alcohol at 30°C is 13.5 kPa.

i) Determine the minimum water rate required for countercurrent flow of liquid and gas, assuming isothermal, isobaric conditions and that only alcohol is absorbed. **[9]**

ii) Determine the number of theoretical stages required for a liquid rate twice the minimum. **[6]**

b) An acetone–air mixture containing 0.015 mole fraction of acetone has the mole fraction reduced to 1 per cent of this value by countercurrent absorption with water in a packed tower. The gas flowrate G is 1 kg/m^2s of air and the water enters at 1.6 kg/m^2s. For this system, Henry's law holds and $y_e = 1.75x$, where y_e is the mole fraction of acetone in the vapour in equilibrium with a mole fraction x in the liquid. How many overall transfer units are required? **[10]**

QUESTION B2

a) Industrial equipment for solid–liquid extraction is designed for batch-wise or continuous processing. The method of contacting solids with solvent is either by percolation of solvent through a bed of solids or by immersion of the solid in the solvent followed by agitation of the mixture. When immersion is used, counter-current, multistage operation is common. With percolation, either a stage-wise or a differential contacting device is appropriate. The 3 commonly used equipment are the Kennedy extractor, the Pachuca tank, and the Shanks system. With the aid of diagrams, explain the principles of operation of these 3 pieces of equipment. **[15]**

b) 400 kg/s of dry sea-shore sand, containing 1 per cent by mass of salt, is to be washed with 600 kg/s of fresh water running counter-currently to the sand through two classifiers in series. It may be assumed that perfect mixing of the sand and water occurs in each classifier and that the sand discharged from each classifier contains one kilogram of water for every two kilograms of sand.

i) If the washed sand is dried in a kiln dryer, what percentage of salt will it contain? **[6]**

ii) What wash rate would be required in a single classifier in order to wash the sand to the same extent? **[4]**

QUESTION B3

The liquid-liquid equilibrium data at 25°C of a ternary acetic acid-benzene-water mixture is given in the following table.

Table B3: Liquid-liquid equilibrium data at 25°C of a ternary acetic acid-benzene-water mixture.

Experiment number	Benzene phase (mass %)			Water phase (mass %)		
	Acetic acid	Benzene	Water	Acetic acid	Benzene	Water
1	0.15	99.85	0.001	4.56	0.04	95.40
2	1.40	98.56	0.04	17.70	0.20	82.10
3	3.27	96.62	0.11	29.00	0.40	70.60
4	13.30	86.30	0.40	56.90	3.30	39.80
5	15.00	84.50	0.50	59.20	4.00	36.80
6	19.90	79.40	0.70	63.90	6.50	29.60
7	22.80	76.35	0.85	64.80	7.70	27.50
8	31.00	67.10	1.90	65.80	18.10	16.10
9	35.30	62.20	2.50	64.50	21.10	14.40
10	37.80	59.20	3.00	63.40	23.40	13.20
11	44.70	50.70	4.60	59.30	30.00	1.70
12	52.30	40.50	7.20	52.30	40.50	7.20

Using the right-angled triangle, illustrate

a) The solubility curve **[6]**

b) Tie lines for experiments numbers. 2, 4, 6 and 8 **[4]**

c) Plait point and conjugate line **[5]**

d) If 100 kg/hr of a solution of acetic acid and benzene containing 30 wt % acid is to be extracted three times with water at 25°C using 40 kg of pure water in each stage, determine the amounts and compositions of the raffinate and extract streams for all three stages. How much solvent would be required if the final raffinate concentration were to be obtained using one stage? **[10]**

END OF QUESTION PAPER