NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

MASS TRANSFER PROCESSES 1B

TCE 2203

Special Supplementary Examination Paper

August 2024

This examination paper consists of 4 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Graph paper, Psychrometric charts

INSTRUCTIONS

1. Answer **ANY FOUR** questions.
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
1.	**25**
2.	**25**
3.	**25**
4.	**25**
5.	**25**
TOTAL ATTAINABLE	**100**

QUESTION 1

a) Explain why mass transfer is a major factor in separation processes and state what limits the extent to which any separation operation can be achieved. **[4]**

b) The degree of separation is often specified in terms of component recovery or product purity. How do these two differ? **[2]**

c) Define flooding, channeling, entrainment, and weeping as conditions experienced on plate gas absorption towers? **[4]**

d) A finely divided solids feed, F, of 150 kg/h, containing 1/3 water soluble Na_2CO_3 and 2/3 insoluble ash is to be leached and washed at 30^0C in a two-stage, countercurrent system with 400kg/h of water. The leaching stage consists of an agitated vessel that discharges slurry into a thickener. The washing stage consists of a second thickener. Experiments show that the sludge underflow from each thickener will contain 2kg of liquid (water and carbonate) per kg of insoluble ash. Assuming ideal stages:

i) Calculate the % recovery of carbonate in the final extract. **[10]**

ii) If a third stage is added, calculate the additional carbonate recovered. **[5]**

QUESTION 2

a) One separation stage is rarely sufficient to produce pure commercial products. Cascades, which are aggregates of stages, are needed to accomplish separations that cannot be achieved in a single stage, reduce the amounts of mass- or energy-separating agents required, and make efficient use of raw materials. With the aid of diagrams. explain the three possible cascade configurations or stage arrangements that can be used to accomplish separation in the chemical industries. **[6]**

b) Dryers can be classified in a number of ways. State any three of these methods giving two examples of dryers that fall in each class. **[6]**

c) What is the differences between relative humidity and percentage humidity? **[1]**

d) Fifty thousand kg/h of flaked soybeans, containing 20 wt% oil, is leached of oil with the same flow rate of n-hexane in a counter-current-flow system consisting of an ideal leaching stage and three ideal washing stages. Experiments show the underflow from each stage contains 0.8 kg liquid/kg soybeans (oil-free basis).

(i) Determine % recovery of oil in the final extract. **[5]**

(ii) If leaching requires three of the four stages such that one-third of the leaching occurs in each stage, followed by one washing stage, determine the % recovery of oil in the final extract. **[7]**

QUESTION 3

a) Leaching is a mass transfer unit operation that is widely used in the chemical industries. Briefly describe the processes for industrial scale commercial application of leaching in the sugar, mining, and oil industries. **[9]**

b) List any three situations under which liquid-liquid extraction might be preferred to distillation. **[3]**

c) A ternary acetic acid-benzene-water mixture is separated into two liquid phases after settling. One phase contains 13.3% acetic acid, 0.40% water and the rest is benzene (all mass %). Determine the composition of the other conjugate liquid phase. **[5]**

d) If the solute composition of the mixture separated in c) above was 19%, use the right-angled triangular coordinates to determine the composition of the feed mixture that would be extracted with pure solvent in a single stage, to get the mixture. **[8]**

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

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	10.70
12	52.30	40.50	7.20	52.30	40.50	7.20

QUESTION 4

a) For specified feed and desired products, the selection of a feasible mass transfer operation is influenced by the following five factors

i) Feed conditions
ii) Product conditions
iii) Property differences that may be exploited
iv) Characteristics of separation operations
v) Economic and environmental considerations

For each of these factors, explain the two most important parameters. **[10]**

b) Define total-moisture content, free-moisture content, equilibrium-moisture content, unbound moisture, and bound moisture. **[5]**

c) Gas, from a petroleum distillation column, has its concentration of H_2S reduced from 0.03 kmol H_2S/kmol of inert hydrocarbon gas to 1 per cent of this value, by scrubbing with a triethanolamine-water solvent in a countercurrent tower, operating at 300 K and at atmospheric pressure. H_2S is soluble in such a solution and the equilibrium relation may be taken as $Y = 2X$, where Y is kmol of H_2S kmol inert gas and X is kmol of H_2S/kmol of solvent. The solvent enters the tower free of H_2S and leaves containing 0.013 kmol of H_2S/kmol of solvent. If the flow of inert hydrocarbon gas is 0.015 kmol/m^2s of tower cross-section and the gas-phase resistance controls the process, calculate the height of the absorber necessary, and the number of transfer units required. *The overall coefficient for absorption K_Ga is 0.04 kmol/sm^3 of tower volume (unit driving force in Y).* **[10]**

QUESTION 5

a) Experimental data are provided for an absorption system to be used for scrubbing ammonia (NH_3) from air with water. The water rate is 1.5 times the minimum and the gas rate is 0.250 m^3/min at 72°C. The air to be scrubbed has 1.5% (volume basis) NH_3 at 72°C and 1 atm pressure and is to be vented with 95% of the ammonia recovered. The inlet scrubber water is ammonia-free. The system is assumed to be ideal and the vapor pressure of ammonia at the prevailing conditions is 13.5kN/m^2. Determine the required number of stages. **[10]**

b) An air-water vapor mixture which has a dry-bulb temperature of 20°C and a wet-bulb temperature of 11°C at 1atm is heated at constant humidity to 50°C. Determine the final values for:

i) Absolute humidity **[3]**
ii) Saturation humidity **[3]**
iii) Specific volume of the air **[3]**
iv) Percentage humidity **[3]**
v) Relative humidity **[3]**

END OF QUESTION PAPER

Universal Industrial Gases, Inc.

PSYCHROMETRIC CHART

BAROMETRIC PRESSURE 760 mm of Mercury