UNIVERSITI
TEKNOLOGI
PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE : CEB2013/CFB2013 - SEPARATION PROCESS I

DATE : 9 AUGUST 2024 (FRIDAY)

TIME : 9.00 AM - 12.00 NOON (3 HOURS)

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **FIVE (5)** pages in this Question Booklet including the cover page .

ii. **DOUBLE-SIDED** Question Booklet.

iii. **Graph papers will be provided.**

1. a. Using appropriate equations, compare the flux estimation for molecular diffusion and diffusion under convection.

[4 marks]

b. Hydrogen and cyclohexane are diffusing in counter diffusion through a straight glass tube at 101.32 kPa and 288.6 K. The pressures on the sides of the tube are 2.5 kPa and 0.2 kPa. The diffusivity of hydrogen is 4.5×10^{-5} m^2/s, and the total pressure is constant throughout the tube. Discuss the effect of diffusion path on the hydrogen diffusion flux through the tube.

[4 marks]

c. A drop of liquid toluene is kept at a uniform temperature of 25.9°C and is suspended in a large volume of still air at 1 atm. The initial radius of the liquid toluene is 2.00 mm. The vapor pressure and the diffusivity of toluene in air at 25.9°C are 3.84 kPa and 7.85×10^{-6} m^2/s, respectively. Derive an equation of diffusion flux in term of partial pressure and determine the diffusion flux, N_A. Assume gas constant, R = 8314.34 $m^3 \cdot Pa/kgmol \cdot K$.

[10 marks]

d. A volatile organic solvent is used to dissolve chlorine (Cl_2) gas leaving the chimney. For the purpose of design calculations, prove that the overall solvent mass transfer resistance is controlled by Cl_2 gas phase.

[7 marks]

2. a. A batch distillation unit is used to distill 800 moles of a binary mixture of acetone and methanol. The initial and final concentrations of acetone are 0.3 and x_2 moles, respectively. Assume that the amount of liquid left is 180 moles. Develop a material balance for the distillation process.

[6 marks]

b. A distillation column receives an equimolar mixture of styrene (C_8H_8) and ethylbenzene (C_8H_{10}) at a rate of 150 kmol/h. The purities of the top product (C_8H_{10}) and the bottom product (C_8H_8) are expected to have 98 mol% and 99 mol%, respectively. The feed mixture is a saturated liquid operates at 1 atm. The relative volatility of the system is 2.75.

i. Calculate the amount of C_8H_{10} in the distillate and bottom streams.

[4 marks]

ii. Estimate the number of theoretical stages and feed-plate location if the reflux ratio is twice the minimum reflux ratio.

[10 marks]

iii. Based on the result obtained in **part (b)(ii)**, determine the actual number of theoretical stages needed for a 75% overall column efficiency. Suggest an example of a tray design appropriate for this distillation process.

[5 marks]

3. a. An air stream with total flowrate of 60 kmol/h containing 5 mol% sulfur dioxide (SO_2) is to be fed to an absorption tower at 293 K and 1 atm. It is desired to remove 95% of the SO_2 under counter current flow.

i. Determine the number of stages in the tower using Kremser's equation if pure water with total flowrate of 160 kmol/h is used as the solvent. Assume the equilibrium relation for SO_2 in the gas-liquid system is $y^2 = 4x^2$, where y is the mole fraction of SO_2 in gas phase and x is the mole fraction of SO_2 in liquid phase.

[9 marks]

ii. Estimate the number of stages in the tower using a graphical method if pure water with total flowrate of 180 kmol/h is used as the solvent. Assume the equilibrium relation for SO_2 in the gas-liquid system is $y = 0.3x - 0.013$, where y is the mole fraction of SO_2 in gas phase and x is the mole fraction of SO_2 in liquid phase.

[12 marks]

b. With the aid of a x-y diagram, draw the location of operating lines for absorption, stripping, and minimum liquid flow operations.

[4 marks]

4. a. Compare and discuss the characteristics of equilateral triangular and rectangular coordinates used for representing the equilibrium data for a three-component system in a liquid-liquid extraction process.

[7 marks]

b. Differentiate **THREE (3)** types of process flow for multi-stage liquid-liquid extraction systems with proper descriptions. Derive the mass balance equation for the final stage.

[8 marks]

c. A treated ore containing inert solid gangue and copper sulphate ($CuSO_4$) is to be leached in a single stage process extractor using pure water. A total of 22 wt% of the $CuSO_4$ in the inlet ore is to be leached. Based on the economic analysis, the optimum ratio of the inlet ore to the solvent was found to be 1:1. The concentration of inert solid (N) for exit underflow is constant at 2 kg insoluble solid/kg solution. Determine the composition of the overflow and underflow leaving the process using graphical method.

[10 marks]

-END OF PAPER-