Ref: EX/CHE/T/113/2017

Bachelor of Chemical Engineering 1st year 1st Semester Examination, 2017

Fundamentals of Chemical Engineering

Time: 3h Full Marks: 100

Answer any five questions

Assume any missing data

1. (a) The *n+1* data points $(x_0, y_0), (x_1, y_1), ..., (x_n, y_n)$ are to be fitted through the 'best' straight line $y = a_0 + a_1 x$. Derive the expressions to estimate the magnitude of a_0 and a_1 from the data. (8)

   (b) Use Newton's Interpolation formulae (forward difference) to developing an equation relating y and x for the following data points (12)

y	-2	-1	0	1	2
x	-16	-19	-20	-13	8

2. (a) The mass fraction of the components of a gas mixture comprised of CO_2, CO, O_2 and N_2 are 10%, 25%, 25% and 40% respectively. Determine the average molecular weight of the gas mixture. (6)

   (b) A water solution containing 10 wt% NaoH (stream *A*) is added to another solution (stream B) containing 25 wt% NaoH flowing at 20 kg/min. The product of the combination leaves at 100 kg/min.

   (i) What is the composition of the mixed stream and the flow rate of stream A?

   (ii) What is the volumetric flow rate of the mixed stream (m^3/min)? (8)

   The density of NaoH is related to the %w/w NaOH (w) by the following equation

$$\rho(\mathrm{g/cm^3}) = 0.0107w + 1.0022$$

   (c) Convert $\frac{6(\mathrm{in})(\mathrm{cm}^2)}{(\mathrm{yr})(\mathrm{lb_m})(\mathrm{ft}^2)}$ to all SI units (6)

3. (a) The heat transfer coefficient, h for heat transfer by natural convection from a flat vertical plate depends on the length of the heated section (L), acceleration due to gravity (

g), density(ρ), viscosity(μ), heat capacity(C_p), thermal conductivity (k), coefficient of thermal expansion (β), the temperature difference between the fluid and heated plate(ΔT). Find the dimensionless form of the governing equation using Buckingham method. (16)

(b) Explain without differentiating whether the following differentiation is correct

$$\frac{d}{dx}\sqrt{1+\left(\frac{x}{a}\right)^2} = \frac{2ax}{\sqrt{1+\left(\frac{x}{a}\right)^2}}$$

where x is the length and a is a constant. (4)

4. It is desired to heat sand (heat capacity = 830 J/kg°C) by contacting with hot air (heat capacity = 1003 J/kg°C) flowing counter-currently in a heat exchanger.

(i) Derive the expression of the operating line in terms of the flow rate of sand and air, and the inlet and/or exit temperatures of these phases? (4)

(ii) Sketch a diagram showing the operating line and the equilibrium line. Mark the inlet and outlet temperature of the phases. Explain whether the operating line will be above or below the operating line? (6)

The flow rate, inlet and outlet temperature of sand entering and leaving the heat exchanger is 10 kg/s, 30 °C and 85 °C respectively. The inlet temperature of air entering the heat exchanger is 100 °C.

(iii) If the temperature of sand at a cross section within the heat exchanger is 50 °C, what will be the corresponding temperature of air at that cross section? The flow rate of air can be considered to be 20 kg/s? (4)

(iv) What should be the minimum flow rate of air for attaining the specified change of sand temperature, flow rate of sand and inlet air temperature? Explain with reasons for the answer. (6)

5. (a) A solution (50 L) contains 100 mg/L of a solute X. it is desired to reduce the concentration of X by liquid-liquid extraction. The solution is mixed with a solvent (10 L) in a mixer (1). After separation, the raffinate is added into another mixer (2) along with a fresh 10 L of solvent. Determine the concentration of extraction and raffinate streams from the two mixers considering equilibrium has been attained? The ratio of the concentration of X in extract phase to that in raffinate phase at equilibrium is 5. (12)

(b) A 0.5 molar aqueous solution of sulfuric acid flows into a process unit at a rate of 1.25 m^3/min. The specific gravity of the solution is 1.03. Calculate (8)
(i) mass concentration of sulfuric acid in kg/m^3?
(ii) mass flow rate of sulfuric acid in kg/s?
(iii) mass fraction of sulfuric acid?

6. (a) Write short notes on (i) Cox chart (ii) Unit operation & Unit processes (2x5)
(b) State with relevant equations the method to determine absolute humidity if Antoine's constant of water is known. (5)
(c) Write the steps along with relevant equation to estimate the mole fraction of components in the vapor phase in equilibrium with liquid phase composition if the temperature if known (5)