# Bachelor of Engineering in Chemical Engineering Examination, 2018

( 3rd Year, 1st Semester, Supplementary )

## Separation Processes - I

Time : Three hours | Full Marks : 100

( 50 marks for each Part )

Use a separate Answer-Script for each Part

## PART I

Answer any ***two***

Assume any **missing** data

1. i) A cooling tower receives warm water at $43^0$C at a mass flow rate of 7000 Kg/$m^2$.h. A cooling range of $13^0$C is to be achieved by counter-current contact with air. The air enters at a rate of 4200 Kg/$m^2$.h at a dry bulb temperature of $31^0$C and humidity of 0.01516 Kg/Kg dry air. The overall volumetric mass transfer coefficient is 2500 Kg/$m^3$.h.$\Delta$H. Determine the number of overall gas phase transfer units and the height of packing.

   iii) What are differences between critical moisture content and equilibrium moisture content of a solid?

   20+5

2. i) Sheet material, measuring 1 $m^2$ and 5 cm thick, is to be dried from 45% to 5% moisture under constant drying conditions. The dry density of the material is 450 Kg/$m^3$ and its equilibrium moisture content is 2%. The available drying surface is 1 $m^2$. Experiments showed that the rate of drying was constant at 4.8 Kg/h.$m^2$ between moisture content of 45% to 20% and thereafter the rate decreased linearly. Calculate the total time required to dry the material from 45% to 5%. All moisture contents are on wet basis.

   ii) Discuss Murphree efficiency and point efficiency. Is there a value of the absorption factor, A = L/mG, for which the Murphree efficiency (for liquid in plug flow) is the same as point efficiency?

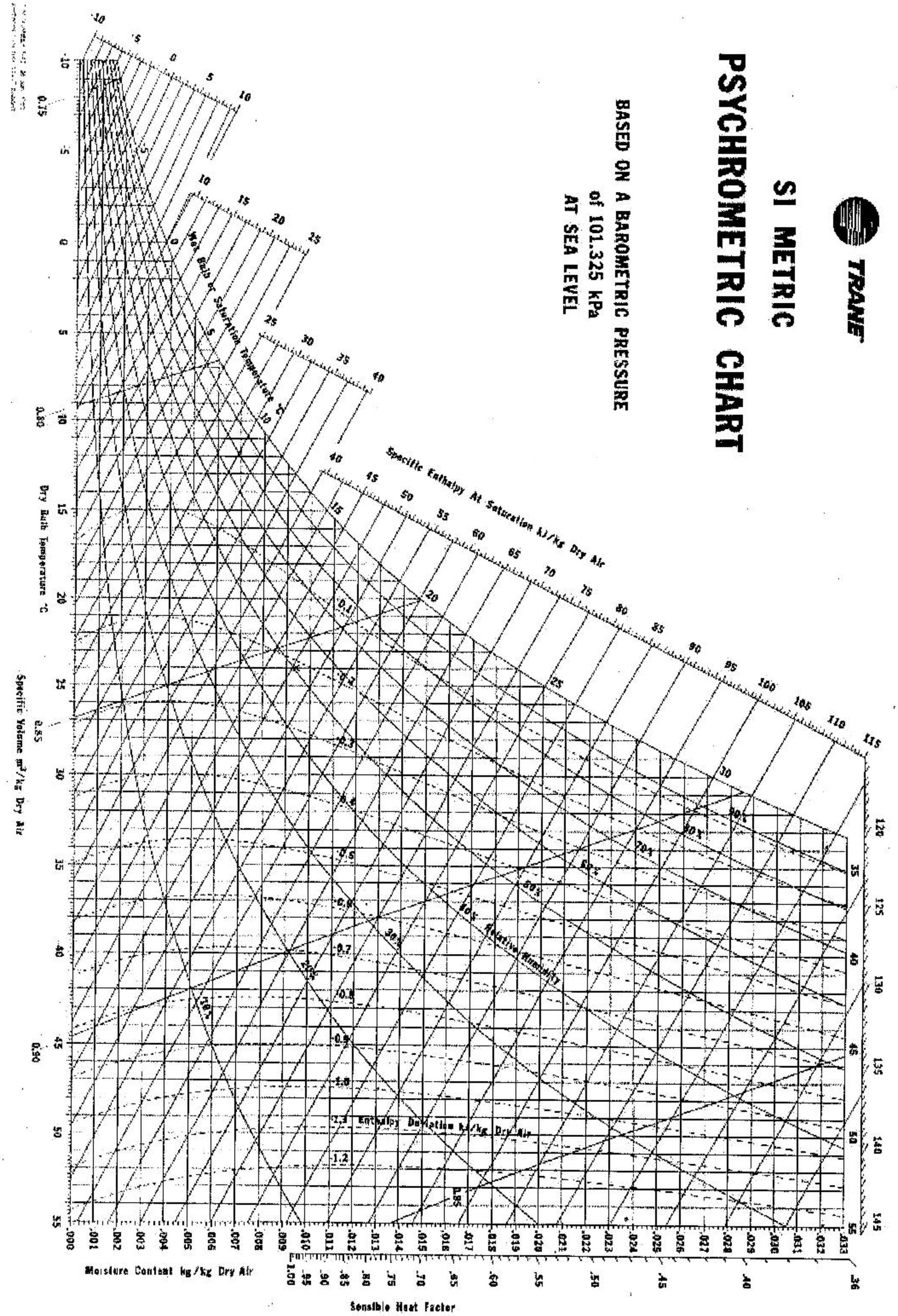
   iii) Make-up water stream must be added during cooling tower operation. Why?

   15+5+5

3. i) In an experimental study of absorption of ammonia by water in a wetted wall column the overall gas phase mass transfer coefficient, $K_G$ was estimated as 2.72 x $10^{-4}$ kmol/$m^2$.s.atm. At one point of the column, the gas contains 10 mol% of ammonia and the liquid phase concentration was 6.42 x $10^{-2}$ kmol ammonia/$m^3$ of solution. Temperature is 293 K and the total pressure is 1 atm. 85% of the resistance to mass transfer lies in gas phase. If Henry's law constant is 9.35 x $10^{-3}$ atm.$m^3$/kmol, calculate the individual film coefficient and interfacial composition.

ii) Ammonia is to be absorbed from air at atmospheric pressure by means counter-current packed tower, using a dilute solution of $H_2SO_4$ as absorbent. In this system, gas film prevents the controlling resistance. The inlet gas rate of 800 lb/hr(ft)$^2$ and acid rate of 1000 lb/hr(ft)$^2$ will be used. Under this condition, $k_{Ga}$ = 18 lbmoles/hr.(ft)$^3$.atm. Determine the tower height needed for absorption of 99% of ammonia from inlet gas containing 1% ammonia by volume in air. The equilibrium relationship is Y = X.

7+18



TRANE
SI METRIC
PSYCHROMETRIC CHART
BASED ON A BAROMETRIC PRESSURE
of 101.325 kPa
AT SEA LEVEL
Specific Enthalpy At Saturation kJ/kg Dry Air
Wet Bulb or Saturation Temperature °C
Relative Humidity
Enthalpy Deviation kJ/kg Dry Air
Dry Bulb Temperature °C
Specific Volume m³/kg Dry Air
Moisture Content kg/kg Dry Air
Sensible Heat Factor

Ref: Ex/ChE/T/311/2018(S)

**B. E. Chemical Engineering 3rd year 1st Semester Examination, 2018**

**Separation Process I**

**Part II**

Answer any two questions

The terms have their usual meaning

Assume any missing data

1. (a) Starting with the following equation $N_A = (N_A + N_B)\frac{C_B}{C} - D_{AB}\frac{\partial C_A}{\partial z}$.

   (i) Derive the expression for $N_A$ for the following cases

   (a) Steady state molecular diffusion in fluids at rest and in laminar flow

   (b) Steady state molecular diffusion of A through nondiffusing B

   (c) Steady state equimolal counter-diffusion

   (d) Methane (*A*) being cracked on a catalyst $CH_4 \rightarrow C + 2H_2$

   (b) A crystal of $NaCl$ of dimension 0.5mmx0.5mmx0.5mm sinks under gravity in a large volume of water. Determine the size if the crystal after it has fallen through 1m.

   It may be assumed that molecular diffusion occurs through a film of size 0.05 mm thick surrounding the crystal. The solubility of NaCl in water is 359 kg/m$^3$ (solution density = 1202 kg/m$^3$). The outer surface of the film is pure water. The diffusion coefficient of *NaCl* may be taken to be 2x10$^{-10}$ m$^2$/s. (16+9)

2. (a) Prove that $\frac{1}{K_x} = \frac{1}{m''k_y} + \frac{1}{k_x}$ (10)

   (b) In an absorption tower, sulfur dioxide present in air is removed by contacting with water. At one point, the gas contained 10% $SO_2$ by volume and was in contact with liquid containing 0.4% SO2 9density = 990 kg/m$^3$). The total pressure is 1 atm. The overall mass transfer coefficient based on gas phase composition was $K_G$ = 7.36x10$^{-10}$ kmol/m$^2$.s. of the total diffusional resistance, 47% lay in the gas phase and 53% in the liquid.

   Equilibrium data is

| Kg $SO_2$/100 kg water | 0.2 | 0.3 | 0.5 | 0.7 |
|---|---|---|---|---|
| Partial pressure SO2,mm Hg | 29 | 46 | 83 | 119 |

(i) Calculate the overall coefficient based on liquid concentration in terms of mol/vol.

(ii) Calculate the individual mass transfer coefficient for the gas expressed as $k_G$ mol/(area)(time)(pressure), $k_y$ mol/(area)(time)(mole-fraction) and $k_c$ mol/(area)(time)(mole/vol) (15)

3. (a) Prove that $F = k_G \bar{p}_{B,M} = k'_G p_t$ (8)

(b) Air at 310 K and atmospheric pressure flows through a smooth pipe 0.025 m ID. The tube is 6 m long. Pressure taps at the ends of the 6m section indicate that the pressure drop is $7\times10^3$ N/m$^2$. Estimate the mass transfer coefficient using (i) Reynolds (ii) Colburn analogy? (10)

Schimdt number and diffusivity may be assumed to be 0.72 and $9\times10^{-6}$ cm$^2$/s respectively.

© Derive the expression given below to determine the depth of packing, Z (7)

$$Z = \int_{y_2}^{y_1} \frac{G\,dy}{F_G a(1-y)\ln\left(\frac{1-y_i}{1-y}\right)}$$