Dr Niloy De 16/11/2023 (1)

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NATIONAL INSTITUTE OF TECHNOLOGY HAMIRPUR

(An Institute of National Importance under Ministry of HRD)

Department of Chemical Engineering

CH-311 MASS TRANSFER I

END SEMESTER EXAMINATION (Session 2023-24)

Maximum Marks: 50 | Time: 3 hour

Instructions:

- Make suitable assumptions, if necessary, by clearly stating them.
- Draw the figure wherever needed.
- Exchange of calculator, pen, pencil etc. are strictly not allowed.
- Graphs should be in pencil

Q1. (2 Marks) (CO4)

A power plant is planning to install two cooling towers to cool process water. Tower 1 needs to cool water from 50°C to 32°C with inlet cold air having wet bulb temperature 25°C. Tower 2 needs to cool water from 50°C to 28°C with inlet cold air having wet bulb temperature 25°C. Which tower according to you need to have a higher packing size and why?

Q2. (6 Marks) (CO1 and CO4)

In a wetted column, a gas A is being stripped from A-water solution into an air stream. At a certain point in the column, the concentration of component A in liquid is 4.8 kmole/m^3 and partial pressure of component Ain gas stream is 1 atm. The equilibrium relation for dilute solution of component A in water is given by $p_{A,i} = 0.25C_{A,i}$, $p_{A,i}$ and $C_{A,i}$ are the equilibrium partial pressure and concentration respectively. The overall liquid coefficient is $K_L = 0.0144$ kmol A/ (hr. m^2. Δx). If the gas phase offers 70% of the total resistance to mass transfer calculate the following

a. convective mass transfer coefficient in liquid phase
b. convective mass transfer coefficient in gas phase
c. Overall mass transfer coefficient in gas phase

Q3. (3 Marks) (CO3 and CO1)

In a refinery plant, gas containing 3% cyclohexane and 95% inerts has to be treated with oil in a packed tower. It is expected to remove 98% of the cyclohexane of the feed gas. The feed solvent is free from cyclohexane. If the feed gas rate is 70 kmol/hr, calculate the minimum solvent rate. The equilibrium relation is given as

$$Y = \frac{0.2X}{1 + 0.8X}$$

Q4. (3 Marks) (CO3 and CO4)

A highly efficient forced draft cooling tower is rated to cool 10000 gph of water from 40 °C to 28 °C. The TDS of the water in circulation must be limited to 500 ppm and that of the makeup water is known to be 250 ppm. Drift loss is half of the total blowdown. Consider evaporation rate is given by: E=(water flow rate in gpm)(range in °F)(0.0008) in gpm. Estimate the rate of blowdown and the makeup water necessary to run the cooling tower.

Q5. (1+4+5=10 Marks) (CO3 and CO4)

A wet solid having 32% moisture is to be dried on a tray dryer to a final moisture 1%. There are two critical moisture values over the whole drying time: $X_{c1} = 0.15$ and $X_{c2} = 0.09$. In the first falling period drying flux is linear in the moisture content; in the second falling rate drying flux is proportional to the square of the moisture content. The equilibrium moisture is negligible. According to the laboratory test, the constant drying rate is $4\ \mathrm{kg/(m^2.h)}$. The solid loading of the dryer is 30 $\frac{\mathrm{kg}}{\mathrm{m^2}}$. Calculate the drying time in the following zone

(a) constant drying period

(b) first falling rate period

(c) second falling rate period.

Consider that the drying time conditions are the same as in the laboratory test. Assume the continuity of drying flux at the second critical moisture content. All of the moisture content are expressed as 'dry basis'. (2+3+5)

Q6. (2×5=10 Marks) (CO4)

Determine the following psychrometric properties of a moist air sample having a dry-bulb temperature 40 °C and wet-bulb temperature of 30°C using the psychrometric chart for air-water system

a. Absolute humidity and relative humidity
b. Dew point
c. Adiabatic saturation humidity
d. Enthalpy
e. Humid volume

The Antoine equations for water is $\ln P_A^{V}(\mathrm{bar}) = 11.96481 - \frac{3984.923}{T-39.724}$, where T is in K. The total pressure is 1 atm. You need to show the respective lines on the graph and complete all of the calculations.

Q7. (10 Marks) (CO1 and CO2)

By what percentage would the rate of absorption be increased or decreased by increasing the total pressure from 100 to 200 kN m^{-2} in the following: (5+5)

a. The absorption of NH_3 from a mixture of NH_3 and air containing 10% NH_3 by volume using pure water as solvent. Assume all the resistance lies in the gas phase.
b. The same continues as in (a) but absorbing liquid exerts partial pressure of NH_3 equal to 5kNm^{-2}. The diffusivity be assumed to be inversely related to absorption pressure.

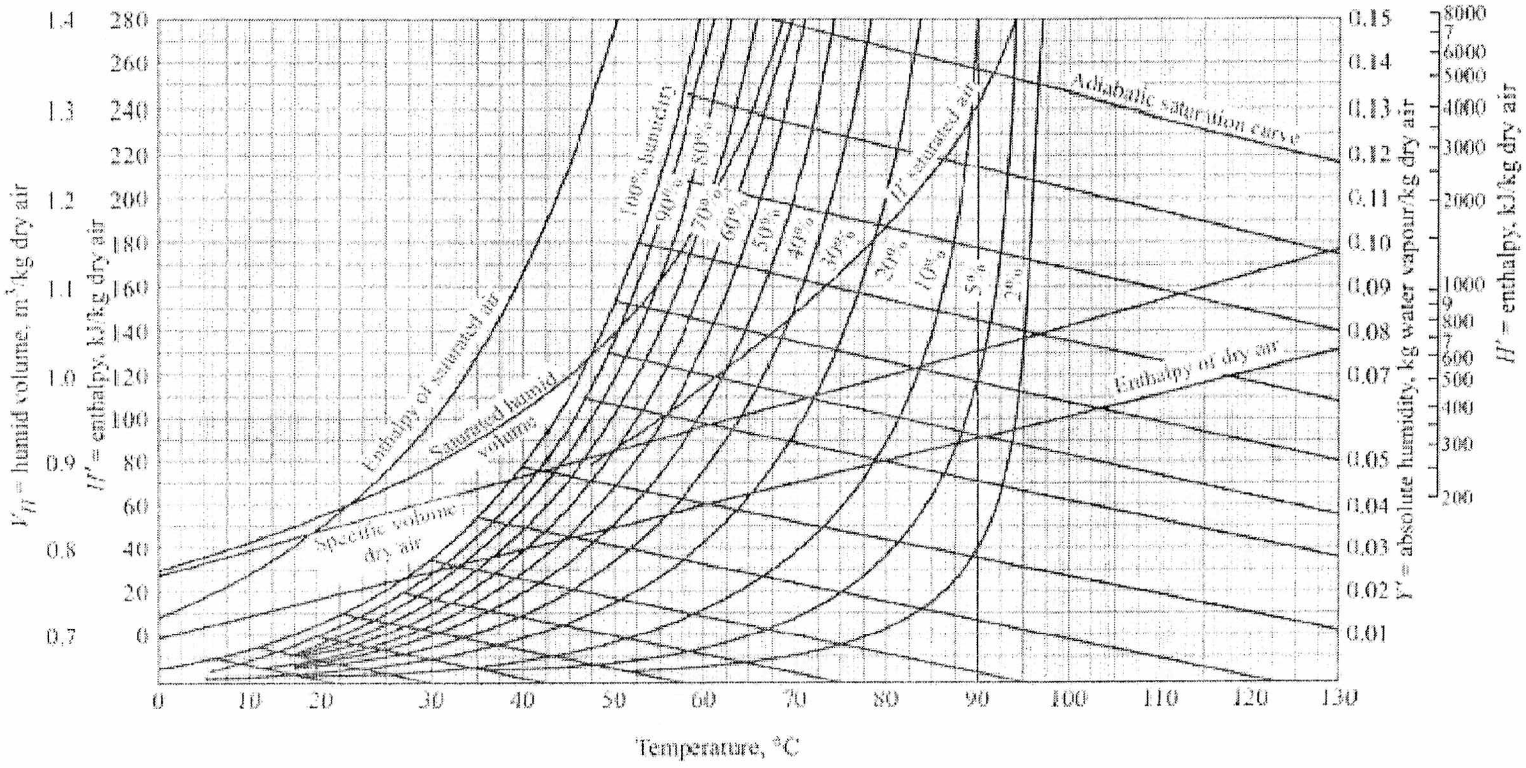
Q8. (6 Marks)(CO4)

The acetone from an acetone-air mixture is scrubbed with water in a packed absorption tower using 1`` Rasching ring. The entering gas mixture has 2 mole % of acetone and the gas leaving the tower is expected to have acetone only to the extent of 0.2 mole %. The gas rate and liquid rate are 160 and 290 kg/hr m^2 respectively. The temperature is 25°C and the pressure is 1 atm. The equilibrium relation is given by $Y = 2.53X$. Following relations are available to calculate the height of transfer units as under in feet:

$$H_G = 6.41\ G^{0.32} L^{-0.51} 1.6^{0.5}$$

$$H_L = 0.01 \left[\frac{L}{1.98}\right]^{0.22} 690^{0.5}.$$

Where G is in $lb/(hr.m^2)(gas)$ and L is in $lb/(hr.m^2)(liquid)$. Determine the height of packed tower. Given data: molecular wt of air is 28 and mol wt of acetone is 58.



Psychrometric chart for the air-water system at 1 atm total pressure