INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

End-Spring Semester Examination, 2012-2013

Subject: Mass Transfer - II *Subject No.*: CH31010

Date: 16.04.2013 (AN) *Time*: 3 Hrs. *Full Marks*: 50

Instructions: Answer **all Questions**. Assume any missing data with proper justifications.

---

1. **(a)** What is a spray chamber? How do the air temperature and humidity profiles vary along the length of a spray chamber?

   (b) What is the major disadvantage of a forced draft cooling tower? Can it be operated with cross flow of air?

   (c) A stream of air is first heated from T_1 to T_2, then fed to a drier where it undergoes adiabatic saturation to temperature T_{as} and finally dehumidified while cooling to T_1 for heating and recycling. Make a sketch of the loop representing the above three steps on the T-Y′ plane.

   d) How is a non-adiabatic evaporative cooler used for dehumidification?

   [1+1+2+1]

2. **(a)** How does the constant rate of drying vary with gas humidity and gas temperature?

   (b) What are the factors that affect the critical moisture content during drying of a material?

   (b) A wet granular solid is placed on a rectangular tray (1.0 m x 0.6 m) and dried in a stream of hot air (temperature, 120°C, humidity, 0.02 kg water/kg dry air), flowing at a velocity of 4.5 m/s. The initial moisture content of 28% (dry basis) is to be reduced to 0.5% (dry basis). From laboratory tests, it is known that the critical moisture content is 12% (dry basis) and the equilibrium moisture is negligible. If the solid loading (dry basis) is 35 kg/m^2, calculate the drying time. The falling rate of drying is linear with moisture content. The convective heat transfer coefficient is given by the expression

   $$\mathbf{h_c = 14.0\ G^{0.8}}$$ (in W/m^2 K with G in kg/m^2 s).

   Latent heat of vaporization of water = 2400 kJ/kg

   [2+1+7]

3. **(a)** What kind of flow strategy is preferred for drying of a heat sensitive substance in a continuous drier?

   (b) What are the factors that affect the equilibrium moisture content of a solid?

   (c) A granular material is to be dried in a counter-current rotary dryer at a rate of 3600 kg/h using air at a rate of 80465 kg dry air/h. The feed contains 50% moisture and the product is discharged with 3% moisture. The entering air is at 107°C and has an absolute humidity of 0.07 kg moisture/kg dry air. The wet material enters at 21°C and leaves at 36°C. The air leaves at 37°C with an absolute humidity of 0.09 kg moisture/kg dry air. The heat loss from the drier surface is estimated at 25 kJ/kg dry air. Determine the diameter and the length of the drier.

   Data: Latent heat of vaporization of water at 0°C = 2450 kJ/kg

   Specific heat of dry air = 0.99 kJ/(kg)(°C); Specific heat of water vapour = 2.01 kJ/(kg)(°C)

   Volumetric heat transfer coefficient, Ua = 150 W/m^3 °C

   For rotary dryers, Ua = 237 G′ $^{0.67}$/D, where G′ is the air rate in kg/m^2.s and D is the drier diameter in meter.

   OR

   (c) A paste material is extruded into cylinders with a diameter of 5.0 mm and length of 25.0 mm and subjected to through-circulation drying. The cylinders are placed on a screen to a depth of 50.0 mm. The density of the dry solid is 1500 kg/m^3 and the bulk density of the dry solid in the bed is 600 kg/m^3. Air at a mass velocity of 0.5 kg dry air/m^2 s and humidity of 0.04 kg water/kg dry air will flow through the bed, entering at 121°C. Calculate the total time required to dry the solid from an initial moisture content of 46% to a final moisture content of 7%. The critical moisture content of the material is 30%. The equilibrium moisture content is given as 0.02 kg moisture/kg dry solid.

   For Re = 90 – 4000 and Sc = 0.6, $j_D = (2.06/\varepsilon)\ Re^{-0.575}$, μ air = 1.95 x 10^{-5} kg/m s

   [1+1+8]

P.T.O.

4. **Answer the following questions:**
(a) In solvent extraction, what is a conjugate curve? Briefly describe how do you draw tie lines using a conjugate curve (make use of an equilateral triangle to illustrate).
(b) Pictorially locate the operating point (ΔR_{min}), on a right angle triangle, corresponding to the minimum solvent to feed ratio for the two cases, i.e., tie lines with positive and negative slopes.
(c) Name any two empirical equations (other than Freundlich) for adsorption isotherms. Give the equation for Freundlich isotherm. What is the range of ***n*** for highly favorable adsorption?
(d) What do you mean by "breakthrough" in adsorption? What is it used for?
(e) Briefly describe the following: *i*) reverse osmosis, *ii*) dialysis, *iii*) pervaporation.

[5]

5. 350 *kg/h* of halibut liver is to be extracted in a counter current cascade with ether to recover oil. The ether which has been partially purified contains 2% oil. The fresh liver contains 20% oil and is to be extracted to a composition of 1% oil (on solvent-free basis). 250 *kg* of solvent is to be used. Assume no adsorption.
(a) What % of oil entering with the liver is recovered in the extract?
(b) How many equilibrium stages are required?

kg oil/*kg* solution	0	0.1	0.2	0.3	0.4	0.5	0.6
kg solution/*kg* exhausted liver	0.288	0.368	0.44	0.51	0.6	0.71	0.87

[6]

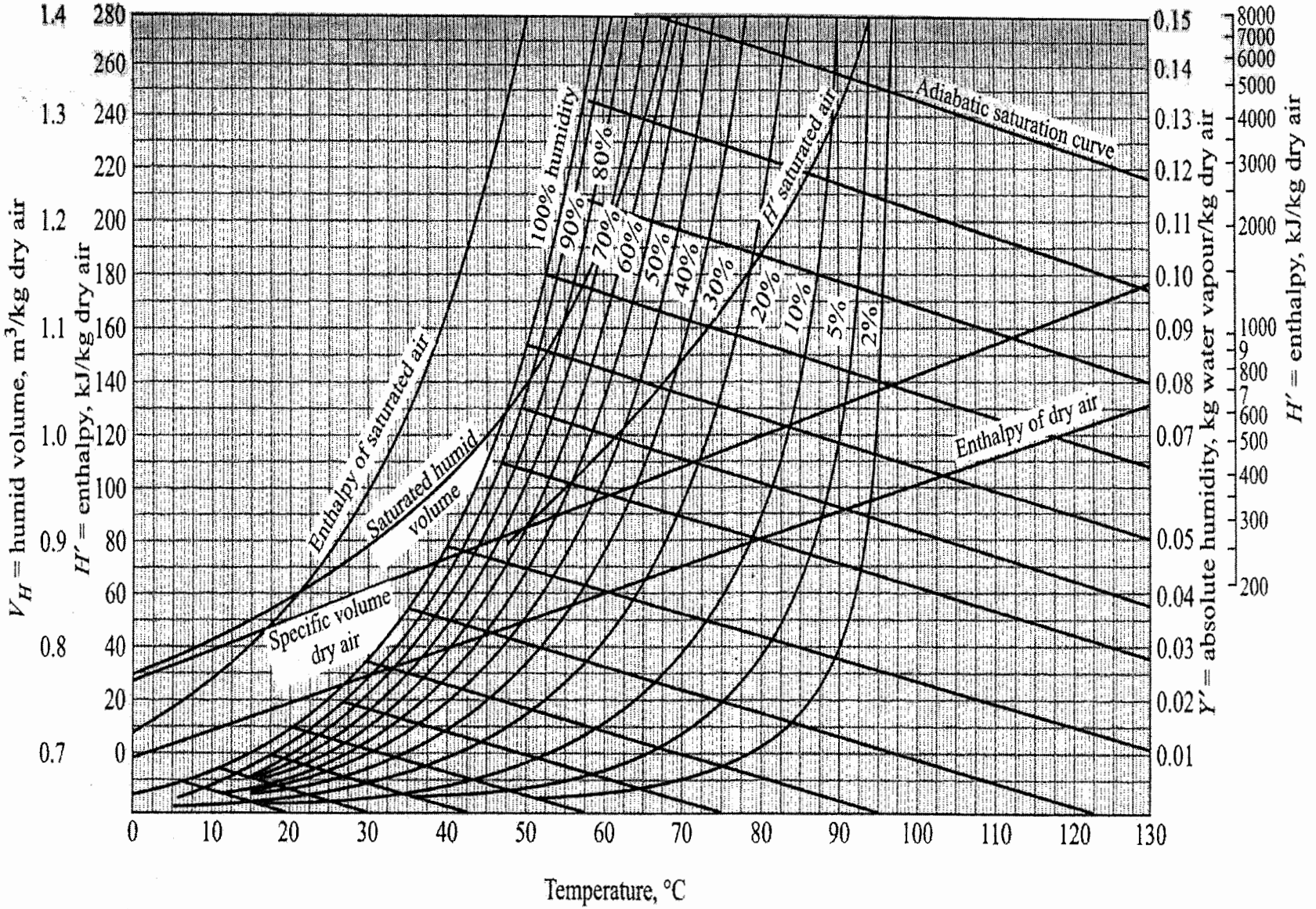
6. $CaCO_3$ precipitate can be produced by reaction of an aqueous solution of Na_2CO_3 and CaO, the byproduct being NaOH. Following decantation, slurry leaving the precipitation tank is 5 *wt*% $CaCO_3$, 0.1 *wt*% NaOH, and the balance water. 100,000 *lb/h* of slurry is fed to a two-stage, continuous, counter-current washing system to be washed with 20,000 *lb/h* of fresh water. Underflow from each thickener will contain 20 *wt*% solids. Determine % recovery of NaOH in the extract and *wt*% NaOH in the dried $CaCO_3$ product. Is it worthwhile to add a third stage? Assume no solids in the overflow and no adsorption of solute on the solids.

[6]

7. A solution of washed raw cane sugar is coloured by the presence of impurities. It is to be decolorized by treatment with an adsorptive carbon in a contact filtration plant. The equilibrium isotherm for this process fits the Freundlich equation of the form $Y = 0.5X$ satisfactorily. If 1000 *kg* of solution containing 20% (by *wt.*) colour is fed to the plant with 500 *kg* of adsorptive carbon, calculate the % colour removed if (a) all 500 *kg* of adsorbent is used in one step, (b) two stages are used with 250 *kg* of adsorbent in each stage.
Also, estimate the minimum amount of adsorbent required for the two stage operation with same recovery and suggest the distribution of amounts of adsorbent in each stage.

[8]

****



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