Charles Darwin University

Final Examination

Family Name						
Given Name/s						
Student Number						
Teaching Period	Semester 2, 2017					

ENG441 – Separation Processes	DURATION	
	Reading Time:	10 minutes
	Writing Time:	180 minutes

INSTRUCTIONS TO CANDIDATES

The paper has only one section. Answer All Questions.

EXAM CONDITIONS

You may begin writing from the commencement of the examination session. The reading time indicated above is provided as a guide only.

This is a CLOSED BOOK examination

Any non-programmable calculator is permitted

No handwritten notes are permitted

No dictionaries are permitted

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
No additional printed material is permitted	1 x 20 Page Book 2 x Scrap Paper

THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

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Total No. of Marks: 100

All questions should be answered in the Answer Booklet provided.
Please Note that All Questions are to be answered.

Marks for each question are indicated. Suggested time allocation: 180 mins

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Question 1

(a) A lab-scale adsorption unit is set up to remove water from a nitrogen gas stream using molecular sieves zeolite with the bulk density of 720 kg/m^3. The zeolite was packed as a bed in a 0.3 m high column and the operation temperature is 28.3^{o}C. The initial water concentration in the adsorbent is 0.01 kg water/kg solid. The mass velocity of the nitrogen gas stream is 1000 kg/h.

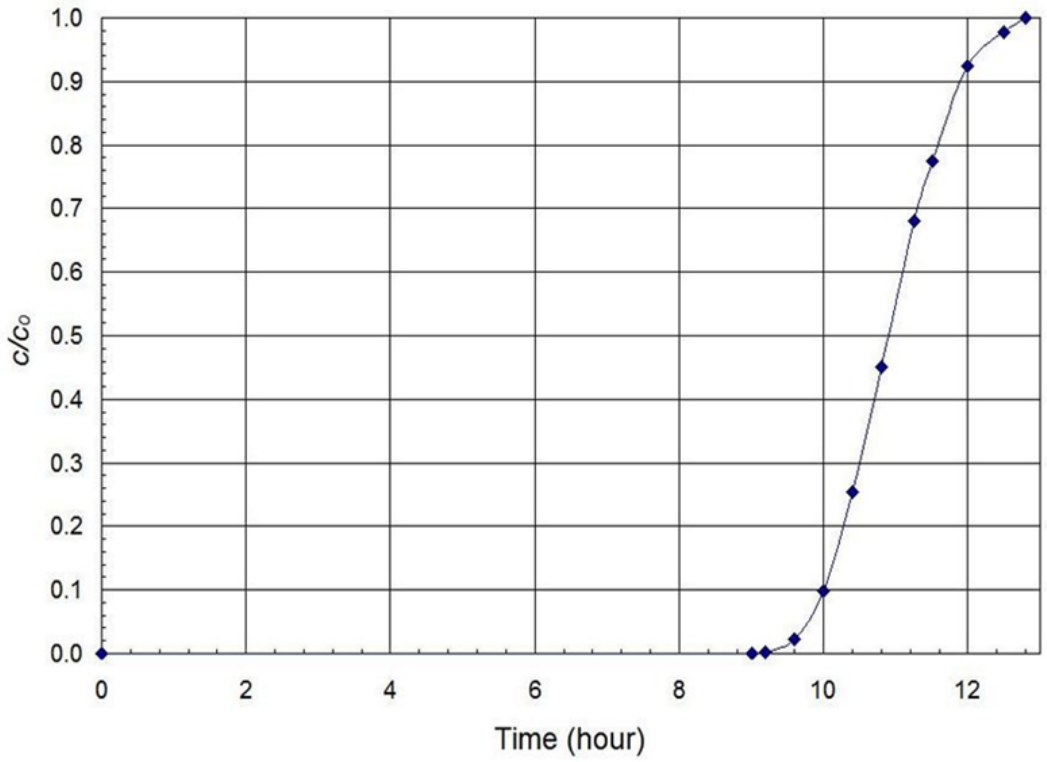

FIGURE Q1 (a): Breakthrough curve for adsorption of water from a nitrogen gas stream using molecular sieves zeolites

The stream contained an initial water concentration, c_0 = 926 x 10^{-6} kg water/kg nitrogen. The desired break point is at c/c_0 of 0.02. FIGURE Q1 (a) shows the breakthrough data obtained using the experimental set up.

I. Determine the new break point time for a new adsorption tower with height of 0.4m.

(Marks: 10)

II. Estimate the saturation loading capacity of the solid for new adsorption tower. Assume the cross sectional area of the column is 0.05 m^2

(Marks: 5)

(b) A finely divided solids feed, F, of 300 kg/h, containing 1/2 water-soluble Na_2CO_3 and 1/2 insoluble ash is to be leached and washed at 30°C in a two-stage, countercurrent system with 800 kg/h of water. The leaching stage consists of an agitated vessel that discharges slurry into a thickener. The washing stage consists of a second thickener. Experiments show that the sludge underflow from each thickener will contain 3 kg of liquid (water and carbonate) per kg of insoluble ash. Assuming ideal stages; Calculate the % recovery of carbonate in the final extract.

(Marks: 10)

Question 2

(a) Solute A is recovered from a dilute solution by dialysis through a membrane. The concentrations of the solution and mass transfer coefficient at different sides of the membrane relevant to this separation are given in **TABLE Q2.**

TABLE Q2: Membrane separation of solute A by dialysis

Feed concentration, c_1	3×10^{-2} kg mol/m^3
Concentration at the permeate side, c_2	0.4×10^{-2} kg mol/m^3
Diffusivity of the solute in the membrane, D_{AB}	3.5×10^{-11} m^2/s
Mass transfer coefficient at the feed side, k_{c1}	1.5×10^{-5} m/s
Mass transfer coefficient at the permeate side, k_{c2}	2.1×10^{-5} m/s
The membrane thickness, L	2×10^{-5} m.
The equilibrium distribution coefficient, K'	0.75

I. Determine the flux at steady state and total percent resistance of the two films.

(Marks: 10)

II. If the velocities of both liquid phases are doubled, predict the total percent resistance on the two films. In this condition, mass transfer coefficients increase as proportional to $v^{0.6}$, where v is the velocity

(Marks: 5)

(b) You wish to batch distill 60 kmol of 32% ethanol (X_F), 68 mol% water feed. The system has a still pot plus two equilibrium stages and a total condenser. Reflux is returned as saturated liquid and reflux ratio is 0.67. You desire a final still pot composition of 4.5 mol% ethanol ($X_{W,final}$). The compositions of top (x_D) and bottom product (x_W) with constant reflux ration obtained from McCabe Thiele diagram for this multi-stage batch distillation is represented in **FIGURE Q2 (b).** The area under the curve shown in **FIGURE Q2 (b)** can be expressed as:

$$Area = \frac{(X_F - X_{W,final})}{6}\left[\left(\frac{1}{X_D - X_W}\right)\Big|_{X_{W,final}} + 4\left(\frac{1}{X_D - X_W}\right)\Big|_{\frac{(X_{W,final} + X_F)}{2}} + \left(\frac{1}{X_D - X_W}\right)\Big|_{X_F}\right]$$

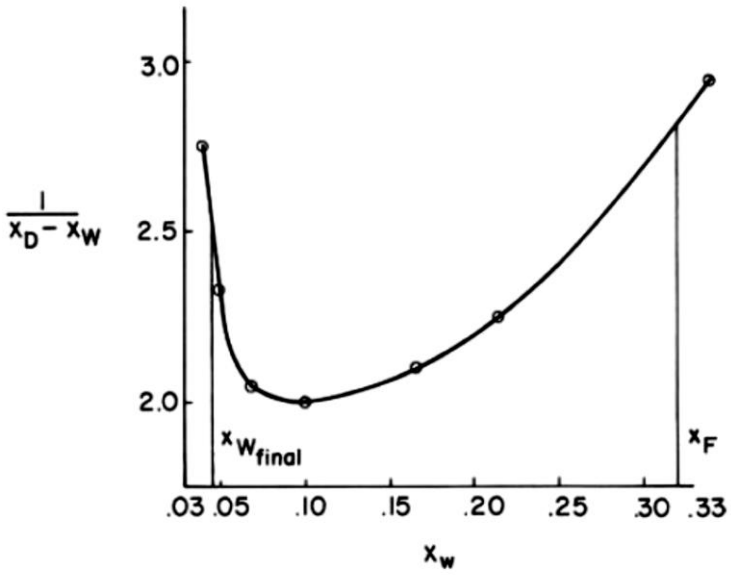

FIGURE Q2(b): Multistage batch distillation data with constant reflux ratio.

Develop the schematic for the process and find the average distillate composition, the final charge in the still pot and the amount of distillate collected.

(Marks: 10)

Question 3

(a) A mixture of water and n-butanol is being processed in an enriching column coupled to a total condenser and a liquid-liquid settler. The feed is a saturated vapor that is 28 mol% water. Feed rate is 100 kmol/h. The distillate product is the water phase from the liquid-liquid settler. The butanol phase in the settler is refluxed to the enriching column as a saturated liquid. Operation is at 1.0 atm and CMO is valid. An external reflux ratio of L/D = 4.0 is used. Equilibrium plot is available in FIGURE Q3 (a).

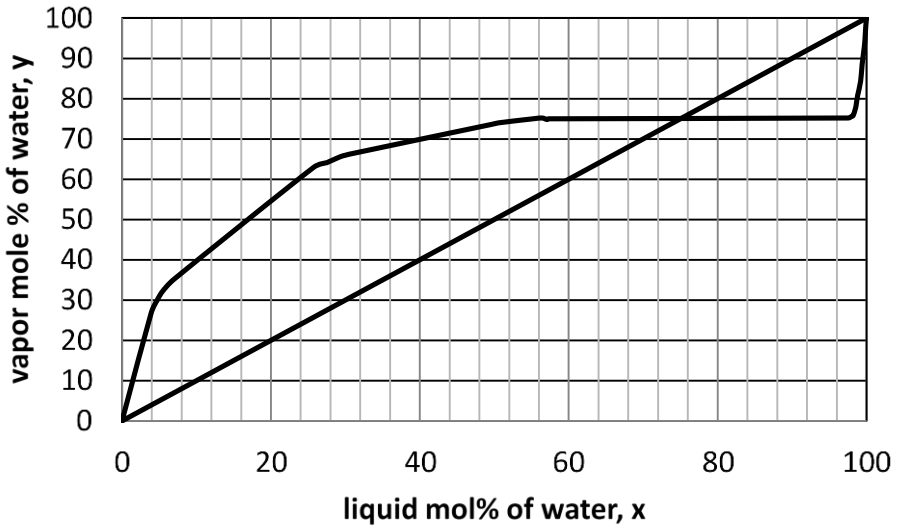

FIGURE Q3(a): Vapor liquid equilibrium plot for water and n-butanol at 1 atm

Suggest the number of stages required for this separation process with necessary calculations. Number of stages to be drawn on FIGURE Q3(a) and to be attached with your answer scripts.

(Marks: 10)

(b) A distillation column is separating methane, ethane, propane, and butane. We pick methane and propane as the keys. This means that ethane is a sandwich component.

I. Show the approximate composition profiles for each of the four components. Label each curve.

(Marks: 4)

II. Explain in detail the reasoning used to obtain the profile for ethane.

(Marks: 5)

(c) A de-ethanizer shown in **FIGURE Q3 (c)** have number of stages equal to 2.5 times of the $N_{min.}$ Estimate the number of stages.

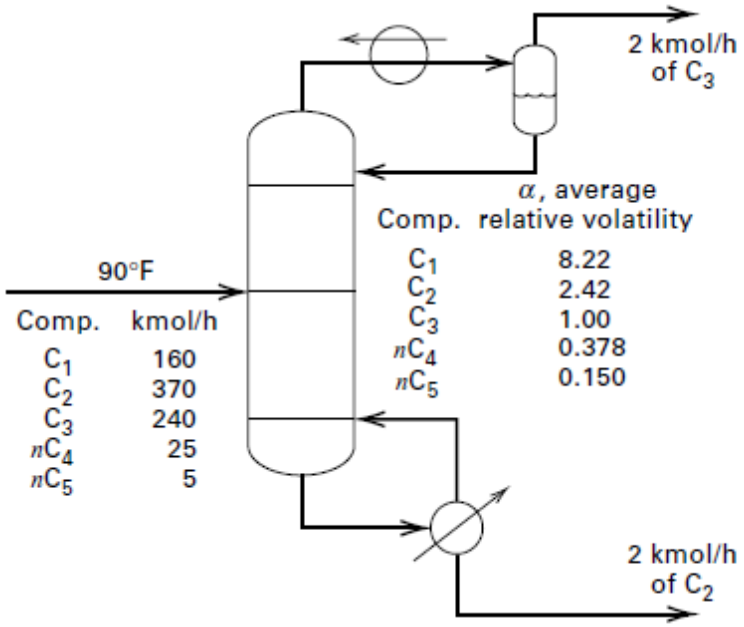

FIGURE Q3(c): Deethanizer with feed and average relative volatilities

(Marks: 6)

Question 4

(a) A single effect evaporator is being used for some time to concentrate a feed of 4590 kg/hr of 2.0 wt% juice solution to 5.0 wt%. The feed solution is entering at 38°C and vapor space pressure is at atmospheric pressure (101.35 kPa). Saturated steam at 110°C is used for heating.

I. Determine the vapor and concentrated liquid flow rate.

(Marks: 5)

II. Now you are advised to replace the single effect to a double effect evaporator with reverse feeding operation to produce the same product with the same feeding rate and composition as in the single effect. In this new arrangement, the steam temperature and vapor space pressure of the first effect also remain same as the single effect. Heat transfer co-efficient of effect-1 and effect-2 are 1104 W/m^2·°K and 3092 W/m2·°K, respectively. Assuming equal vapor flow rate from each effect of the evaporator, estimate the vapor flow rate and temperature of the second effect.

(Marks: 10)

(b) A wet solid is to be dried in a tray dryer under steady state conditions from initial free moisture content of 0.4 kg H2O /kg dry solid to 0.02 kg H2O/kg dry solid. The critical free moisture content and constant drying rate are 0.19 kg H2O/kg dry solid and 1.514 kg H2O/h·m2, respectively. The weight of dry solid is 99.8 kg and the top surface area for drying is 4.65 m^2. The rate of drying in falling rate region is expressed as,

$$R = 5.5x + 0.4$$

Determine the total drying time and provide your justification on the obtained drying time for constant and falling region.

(Mark: 10)