BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI, PILANI CAMPUS
CHEMICAL ENGINEERING DEPARTMENT
Course Title: Process Design Principles - I (CHE F314)
Mid Semester Test (Closed Book)

Marks: 75 ` Date: 04/10/16 Time: 90 minutes

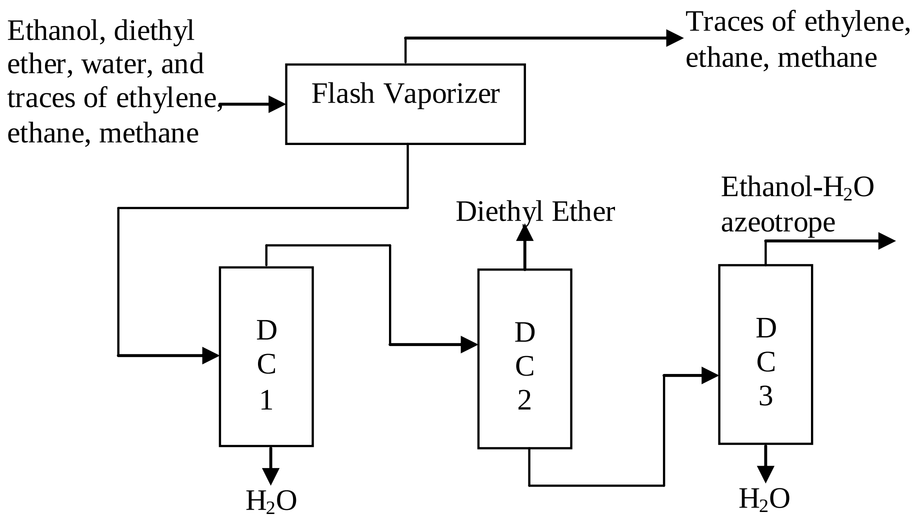
Note: Make the suitable assumption by clearly stating them, if necessary.

1. **(10 Marks)**
   A product stream consists of ethanol, diethyl ether, water, and traces of ethylene, ethane, methane, the boiling points of which are 78.3 ^oC, 34.6 ^oC, 100 ^oC, -103.7 ^oC, -89 ^oC, -164 ^oC respectively. Ethanol forms an azeotrope with water. Propose a flow sheet for the separation of the product components.
2. **(5 + 5 = 10 Marks)**
   (a) Between the Liquid Separation System (LSS) and the Vapor Recovery System (VRS), which should be designed first and why?
   (b) Does the rule of thumb (heuristic), L=1.4 mG, applicable for concentrated solution? If so, why? If not, why not?
3. **(15 Marks)**
   In a peanut processing plant 10 ton/hr of miscella (15 wt% peanut oil in hexane) leaves at 35^{0}C. Distillation is used as one of the economical process to separate the hexane from the oil so that the final oil contains less than 0.01% hexane and such that the temperature never exceeds 80^{o}C. How will you decide the lower and upper bound of the distillation tower operating pressure? Estimate the lower and upper bounds of operating pressure. Carryout appropriate calculations to justify your answer.
   Data Given: Antoine constants for Hexane: A = 15.8366, B = 2697.55, and C = -48.78, Molecular weight of Hexane and Peanut oil are 84 and 885.02 respectively.
   Antoine Eq.: $\ln(p^*) = A - \frac{B}{C+T}$ where, p* = vapor pressure in mm Hg and T = Temperature, K
4. **(15 Marks)**
   Methanol (CH_3OH) is produced by the hydrogenation of carbon monoxide in the gas phase reaction as given below:
   $$CO + 2H_2 \rightarrow CH_3OH \qquad \Delta H_R = -104.69 \text{ kJ/mol}$$
   $$CO + 3H_2 \rightarrow CH_4 + H_2O \qquad \Delta H_R = -198.28 \text{ kJ/mol}$$
   Pure carbon monoxide is used as a feed stream, but the hydrogen stream contains 2% of methane. The reactions take place at temperature 340 ^oC. Allowable temperature range for these reactions are 300 – 400 ^oC. Whether the reactor is operated adiabatically or isothermally? Justify your answer with calculations. If your answer is isothermal, then suggest the way by which isothermal condition would be maintained. Consider 100 moles/h of methanol production and selectively as 0.8. The specific heats in J/mol K of CO = 28.95, H_2 = 28.84, CH_3OH = 52.29, CH_4 = 34.31, H_2O = 33.46. Consider feed rate (per hour) to the reactor as 200 moles CO, 600 moles H_2, 250 moles CH_4. 1 Btu = 1055 J and 1 lb = 453.3 g.
5. **(25 Marks)**
   Ethanol is produced via hydration of ethylene by the following reactions.
   $$C_2H_4 + H_2O \rightarrow C_2H_5OH$$
   $$2C_2H_5OH \rightarrow (C_2H_5)_2O + H_2O$$
   The reactions take place in the batch reactor at 300^0 C and 882 psia. The production rate of ethanol is 200 moles per hour. The feed of ethylene is 98% pure containing 2% methane as an inert. Assume cost of process steam is negligible and diethyl ether is completely recycled back. Develop the recycle structure for ethanol production process and calculate the stream flow rates (inputs, outputs, recycle flows, reactor inlet) in terms of design variables. Selectively is defined as moles of Ethanol produced per mole of ethylene converted.
   Given Data: The boiling points of ethylene, water, ethanol, diethyl ether, and methane are – 103.4 ^oC, 100 ^oC, 78.4 ^oC, 34.6 ^oC and – 161 ^oC respectively.

ALL THE BEST

Solution:

1.



2.

a. No, the heuristic L=1.4 mG is not applicable to concentrated solutions. It is only valid for dilute and isothermal absorbers. It is not applicable because for concentrated solutions, non-linear variation comes in picture when concentrated liquid goes down in the bottom of the absorber. Basically, we obtain curved equilibrium line in case of the concentrated solutions.

b. Design the vapor recovery system (VRS) before we consider the liquid separation system (LRS) because each of the vapor recovery processes usually generates a liquid stream that must be further purified. This liquid stream will be added to LRS which we change the load (total amount of liquid) of LRS.

3. To condense the hexane under vacuum, the vapor pressure of hexane in the condenser must be such that hexane will condense on the heat exchange surface. Cooling water is available at 25^{o}C and the dew point for hexane should be above 25^{o}C. The vapor pressure of hexane is 150 mm Hg at 25^{o}C (using Antoine equation). Thus, I might be able to condense the hexane using available cooling water if the condenser operates above 150 mm Hg, and since I envision the condenser as connected directly to the tower, this might be an estimate of the lower bound of the tower operating pressure.

If steam is to act as an inert gas, it must not condense in the distillation tower. The temperature during separation is not to exceed 80^{o}C. We should calculate the dew point of steam for temperature above 80^{o}C using Antoine equation. This may suggest that the distillation tower should operate less than 400 mm Hg. Hence, distillation tower should operate somewhere in the range of 150 – 400 mm Hg.

4.