ChE-310: Fundamentals of Separation Processes

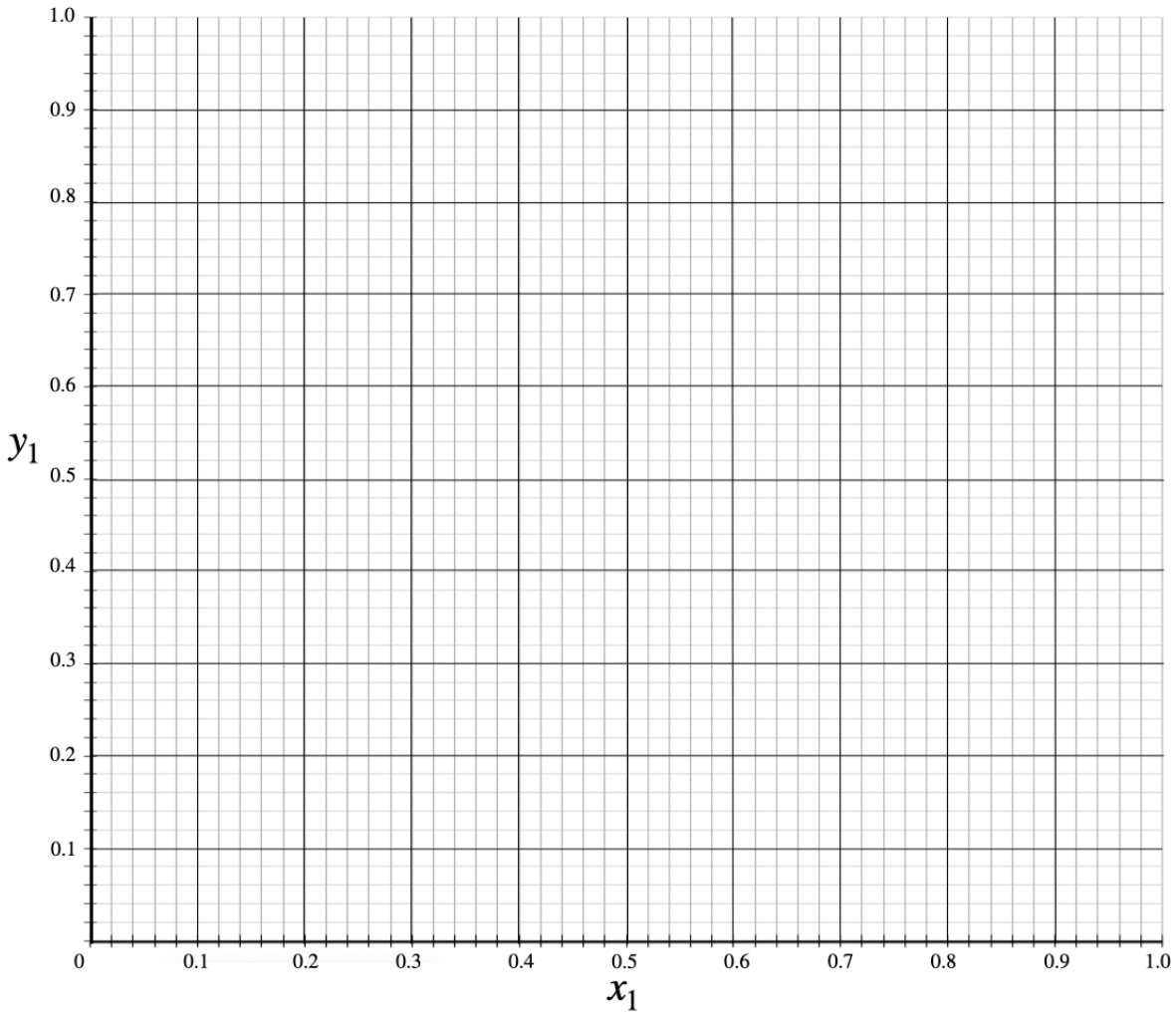
Mid-term exam

- **There are a total of 2 questions. Exam time is 9h30 to 12h00.**
- **Reference to the lecture notes or any other materials is not allowed.**
- **To obtain a full grade, you must write clearly.**
- **Write assumptions if any.**
- **Make sure to indicate your Full Name and SCIPER number on each page of your answer sheet.**
- **Return this exam paper with your solution.**
- **There are total of 4 pages in this exam.**

1. Consider the separation of a binary mixture (components 1 and 2) with a distillation column using a total condenser and a partial reboiler. The boiling point of component 1 is 65 ºC and that of 2 is 43 ºC higher than that of component 1. The feed flow rate is 100 mol/h. The feed has 50% of component 1. They form an ideal solution with constant relative volatility of 5. The desired recovery of component 1 in the distillate is 90%. $x_B = 0.1$. The feed is saturated liquid.

$$y_1 = \frac{\alpha_{12} x_1}{(1 - x_1 + \alpha_{12} x_1)}$$

   a. What is the degree of freedom in this case. **(2 point)**
   b. What will be k_2/k_1 where $k_i = y_i/k_i$ **(2 point)**
   c. Draw a y_1-x_1 phase diagram. **(6 point)**
   d. Mark points on the curve which relate to the boiling points of components 1 and 2. **(4 points)**
   e. Calculate the composition of the distillate. **(2 points)**
   f. Calculate the flow rate of distillate **(2 points)**
   g. Calculate the flow rate of bottom **(2 points)**
   h. What is feed quality. **(2 points)**
   i. What is the minimum reflux ratio (R_{min}). **(6 points)**
   j. Calculate R if the reflux ratio is 3 times R_{min}. **(2 points)**
   k. Calculate the equation for operating line for the rectifying section. **(2 points)**
   l. Calculate the equation for operating line for the stripping section. **(2 points)**
   m. Calculate liquid and vapor flow rates in the rectifying section. **(4 points)**
   n. Calculate liquid and vapor flow rates in the stripping section. **(4 points)**
   o. Calculate boilup ratio by dividing vapor flow rate in stripping section by B. **(2 points)**
   p. Calculate boilup ratio from the operating equation of stripping section and compare with answer in (o). **(2 points)**
   q. Calculate the total number of equilibrium stages and label them ((x1, y1), (x2, y2), etc.). **(4 points)**
   r. How many equilibrium stages are above feed. **(2 points)**
   s. Mark the composition of (x1, y1). **(2 points)**

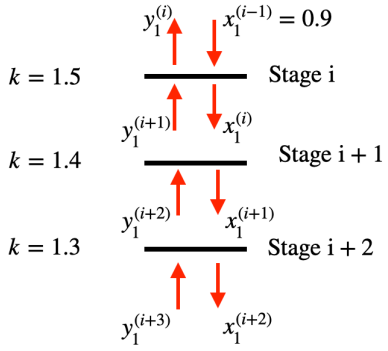

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
y_1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
x_1

2. Consider the separation of a ternary mixture consisting of acetic acid dissolved in water which is being extracted by ethyl acetate. Water and ethyl acetate are partially miscible, and the corresponding phase diagram is provided. The dashed red lines are the tie lines. You decided to use a countercurrent extractor.

   100 kg/h of a feed containing 45 wt% acetic acid, 50 wt% water, and 5% ethyl acetate is fed to an extractor. The inlet ethyl acetate has 10% acetic acid (no water) with a flow rate is 100 kg/h. The exiting raffinate stream should contain 5 wt% acetic acid.

   a. Mark the composition of E_{N+1}, R_0, and R_N in the triangular diagram. **(3 points)**
   b. Calculate the outlet composition of the extract stream. **(4 points)**
   c. Calculate the outlet flow rate of the extract stream. **(4 point)**
   d. Calculate the composition of R_1. **(4 points)**
   e. Calculate the flow rate corresponding to hypothetical point Δ. **(6 points)**
   f. Find the number of equilibrium stages required. **(3 points)**

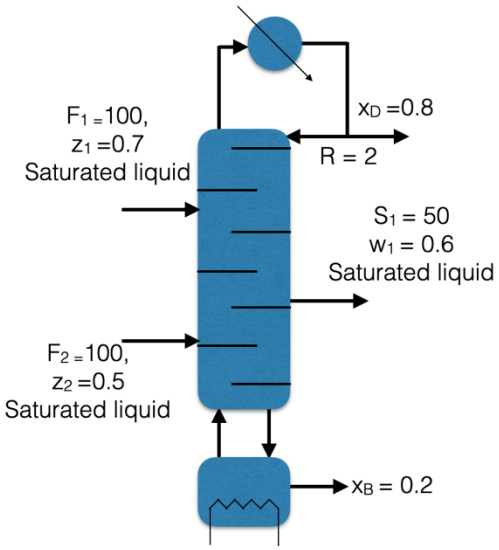
3. You are operating a multicomponent distillation with unique condition of minimum number of stages. For the description provided in the diagram for component 1 between stages i and i+2, calculate y_1^{i+3}. **(10 points)**

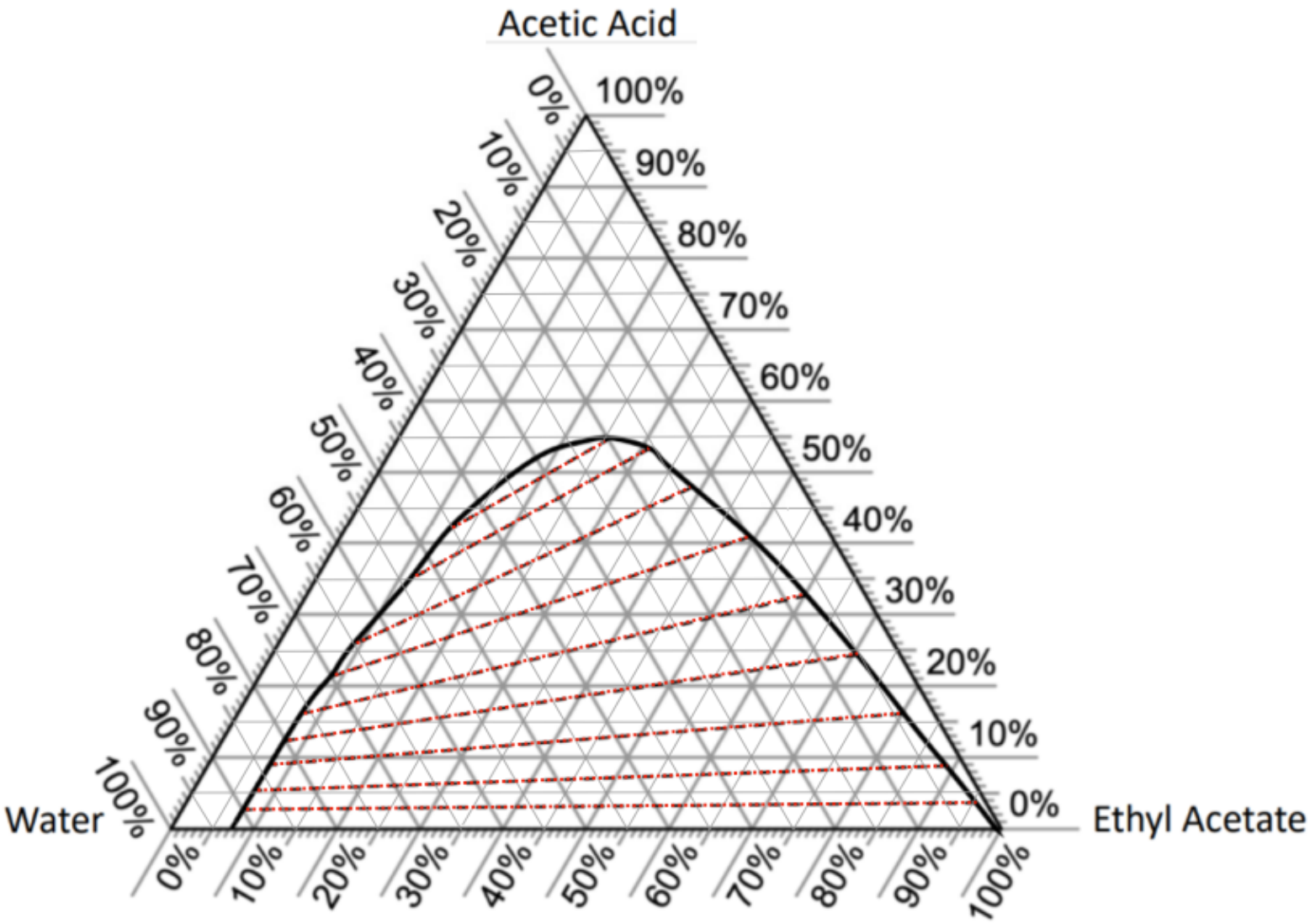


4. Consider the following distillation column with 2 feeds. Calculate vapor and liquid flow rate inside the column in the sections

   a. between the feed F_1 and outlet S_1. **(6 points)**

   b. between the outlet S_1 and feed F_2. **(6 points)**




Acetic Acid
0%
100%
10%
90%
20%
80%
30%
70%
40%
60%
50%
50%
60%
40%
70%
30%
80%
20%
90%
10%
100%
0%
Water
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Ethyl Acetate