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By signing my name below, I affirm that I have not received assistance in completing this examination paper nor have I given assistance to another student. Moreover, as a member of UC Berkeley, you agree to act with honesty, integrity, and respect for others.

Name (print):_____

Name (sign):_____

Chemical Engineering 150B
Midterm Exam 2

November 18, 2024
2:10 pm – 3:00 pm

50 Points Total

Two Problems

Closed book and no lecture notes, no phone or headphones
One two-sided equation sheet
Calculator allowed

This examination has 26 pages,
An equation sheet is provided separately.

Problem 1 _____

Problem 2 _____

Total _____

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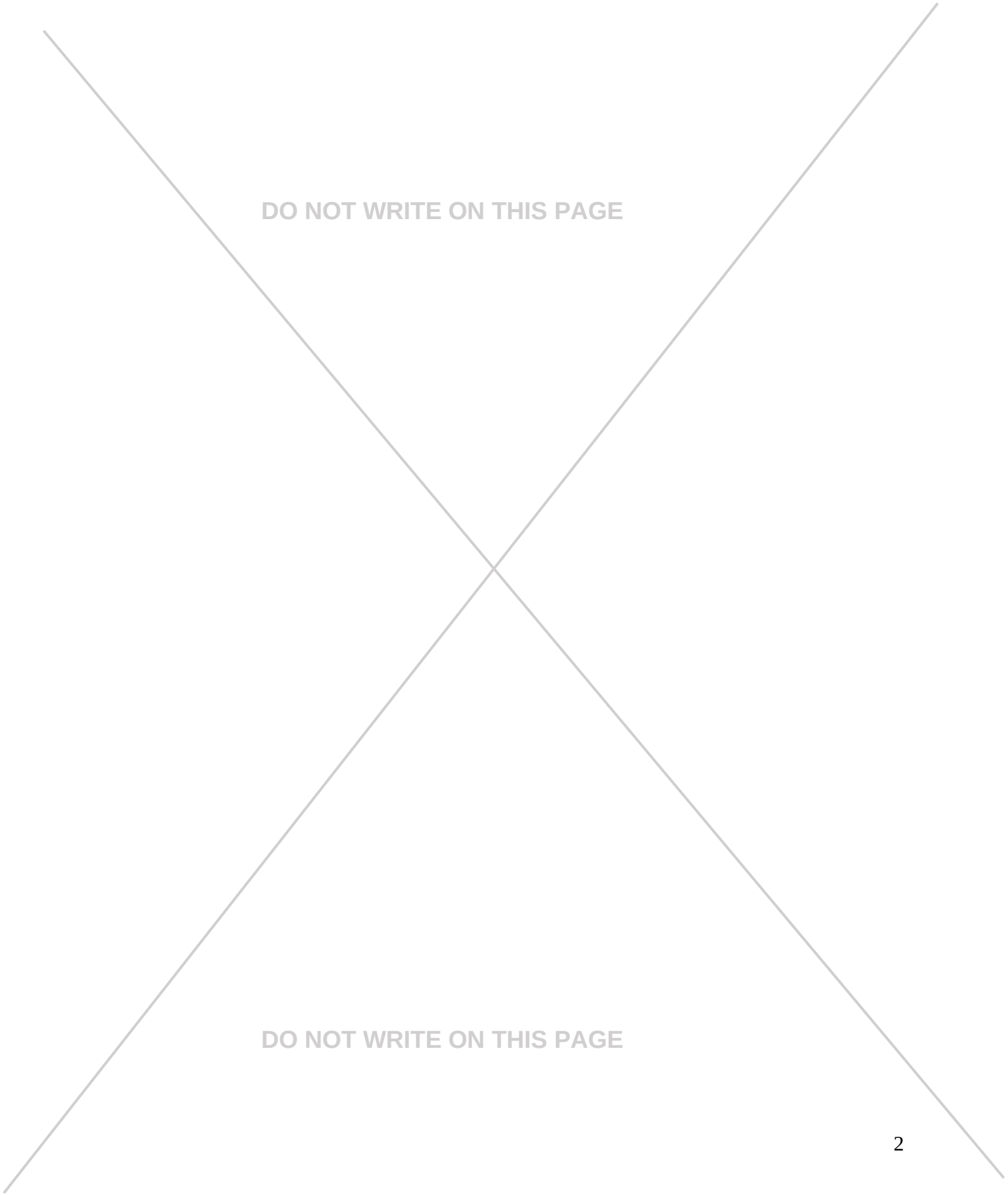

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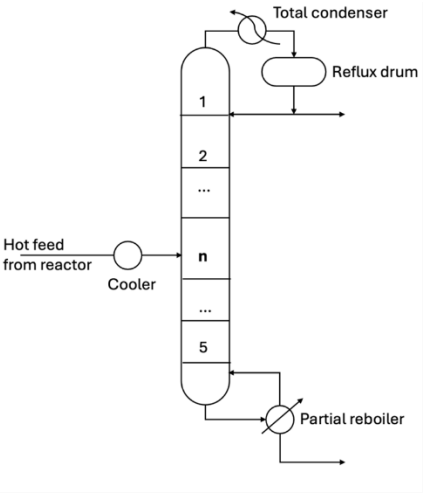
The two questions for the exam are written below and will **be rewritten on subsequent pages** for you to write down your answers. Your work on **this page** will **NOT** be graded.

Problem 1 (25pts).

You are a chemical engineer at Bear Chemical, responsible for overseeing a distillation column used to separate a methanol-water mixture. Last night, a powerful storm swept through the town, causing unexpected disturbances to the system. Your task is to analyze and troubleshoot the issue.

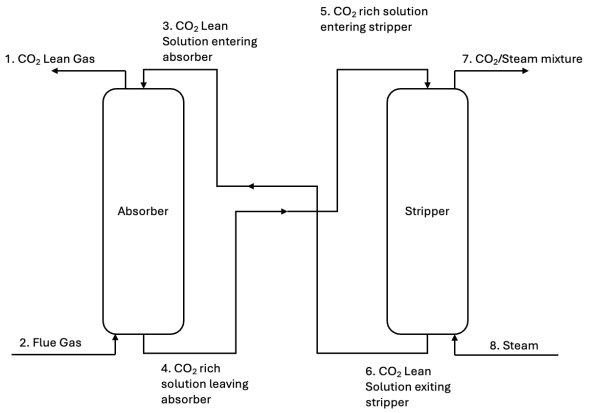


- The column has 5 plates, a total condenser and a partial reboiler.
- A cooling chamber (or cooler) is used to cool down the feed before entering the column to prevent combustion and improve the purity of distillate.
- The pressure indicator shows a normal reading of 101 kPa.
- A feed of 100 kmol/h of 50 mol% methanol was sent to the n-th tray, the optimal location for the feed.
- The column is designed to produce distillate of 90 mol% methanol and bottoms of 10 mol% methanol, with a reflux ratio of 1.

a) **(5pts)** Fill out Table 1 for the normal operation with only numbers. Show your calculation below the table.
b) **(5pts)** Use the chart provided. Is it possible for the feed to be saturated vapor? Show on the graph and explain with one sentence.
c) **(6pts)** If the feed enters the column with a 50% vaporized fraction. Determine the total number of theoretical stages and the optimal feed stage number.
d) **(6pts)** You inspect the column and confirm that all plates are functioning well and the feed is entering at the optimal location. However, different data is reported in Table 2 for the abnormal operation. Based on Table 2, estimate the vaporized fraction (in percent) of the feed using the chart below.
e) **(3pts)** Compare your result in part (c) and (d), circle the part of the schematic where failure most likely occurs and explain with one sentence.

Problem 2. (25pts)

You are tasked to design a carbon capture system that uses an amine solution in the absorber to absorb the CO_2. The Absorber is coupled with a stripper that uses steam to regenerate the absorbant. A set-up is shown below.



Note: Stream 6 and 3 have the same composition & Streams 4 and 5 have the same composition

(a) **(4 pts)** Label streams 1-8 on the Absorber and Stripper (i.e. Y_0 , Y_{N+1}, X_1 etc).
(b) **(10 pts)** Calculate the mole ratio of CO_2 in the flue gas (stream 2), the CO_2 lean gas (stream 1), the CO_2 lean amine solution (stream 3), and the CO_2 rich amine solution (stream 4).
(c) **(6 pts)** Determine the minimum amount of (fresh) steam needed to regenerate the amine solution in the stripping column.
(d) **(5 pts)** You decide to operate the stripper at a steam flow rate of 3.66 kmol/s. What is the composition of the vapor stream leaving the stripper?

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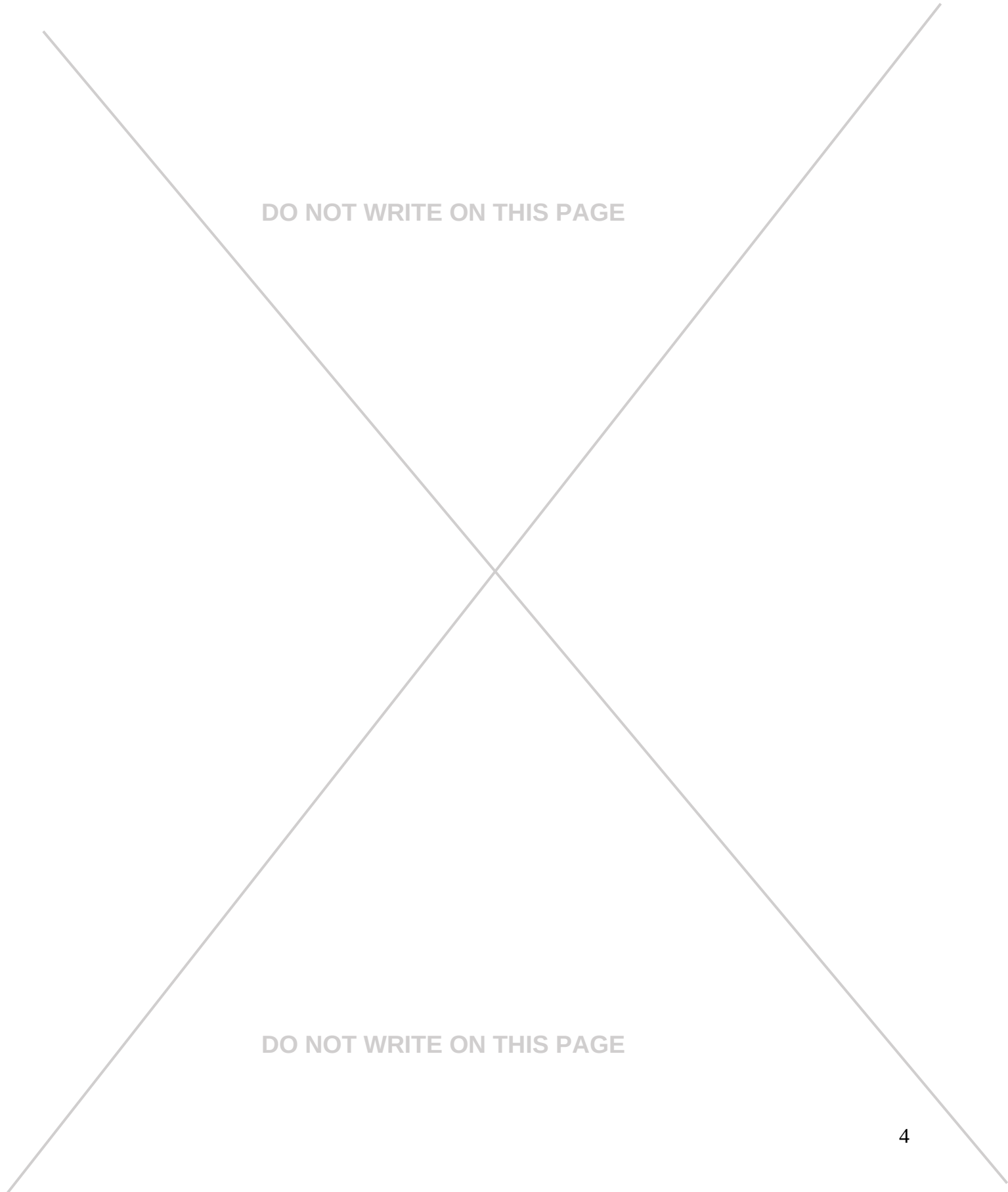

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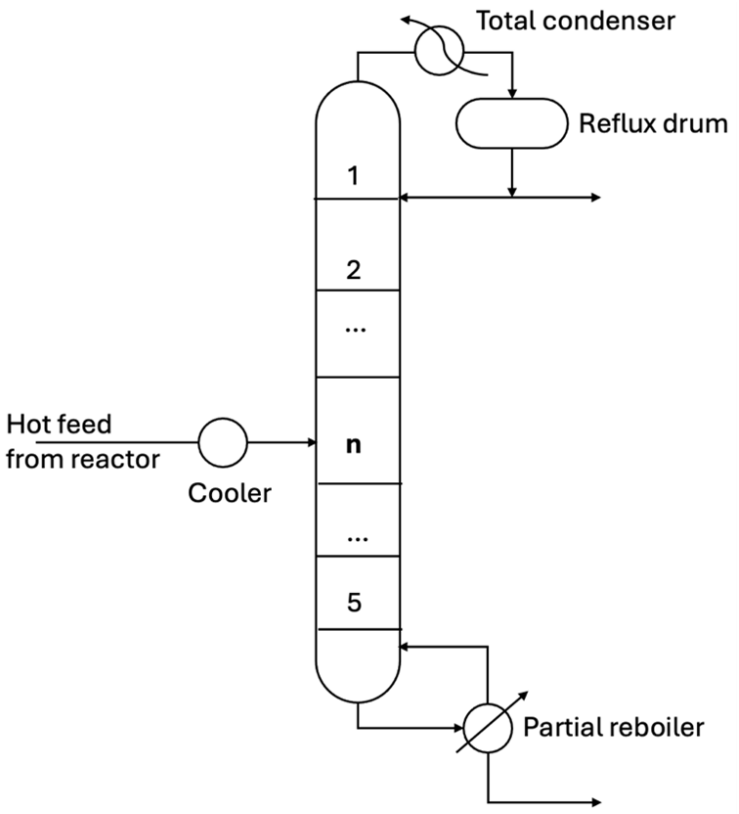
Problem 1. (25 points)

You are a chemical engineer at Bear Chemical, responsible for overseeing a distillation column used to separate a methanol-water mixture. Last night, a powerful storm swept through the town, causing unexpected disturbances to the system. Your task is to analyze and troubleshoot the issue.

- The column has 5 plates, a total condenser and a partial reboiler.
- A cooling chamber (or cooler) is used to cool down the feed before entering the column to prevent combustion and improve the purity of distillate.
- The pressure indicator shows a normal reading of 101 kPa.
- A feed of 100 kmol/h of 50 mol% methanol was sent to the n-th tray, the optimal location for the feed.
- The column is designed to produce distillate of 90 mol% methanol and bottoms of 10 mol% methanol, with a reflux ratio of 1.



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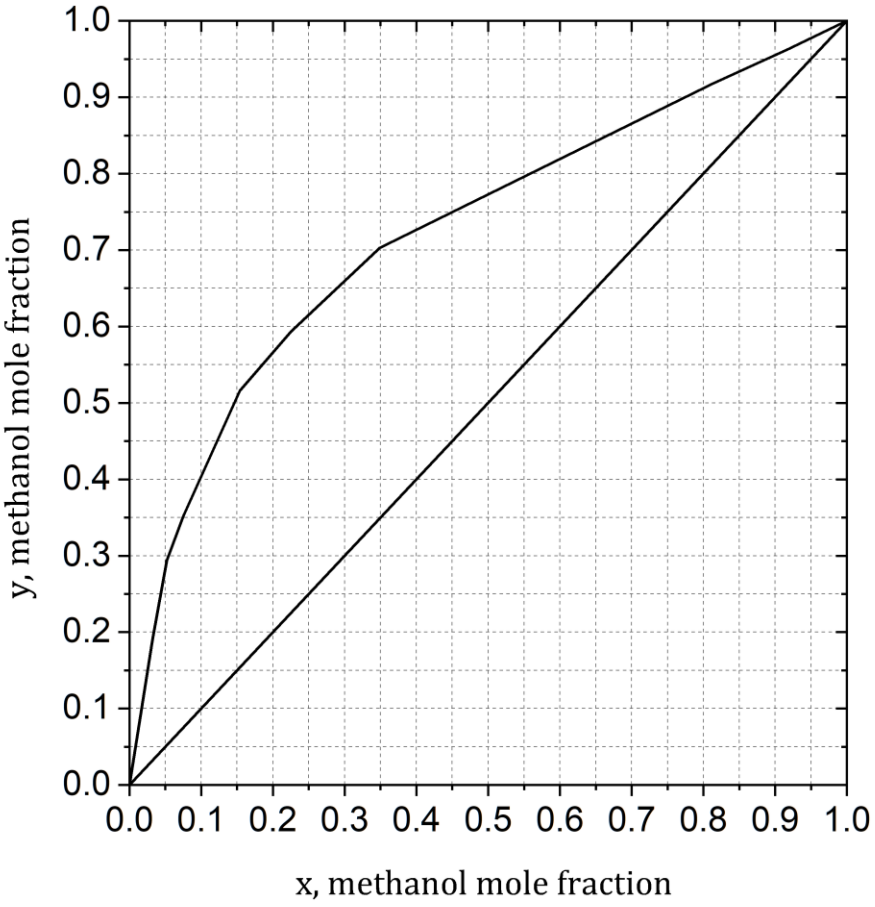
(a) **(5pts)** Fill out *Table 1* for the normal operation with only numbers. Show your calculation below the table.

Stream	molar flow rate (kmol/h)	methanol fraction (mol%)
Feed (F)		
Bottoms (B)		
Distillate (D)		
Overhead vapor (V)		

Table 1. Records of the normal operation

(b) **(5pts)** Use the chart provided. Is it possible for the feed to be saturated vapor? Show on the graph and explain with one sentence.



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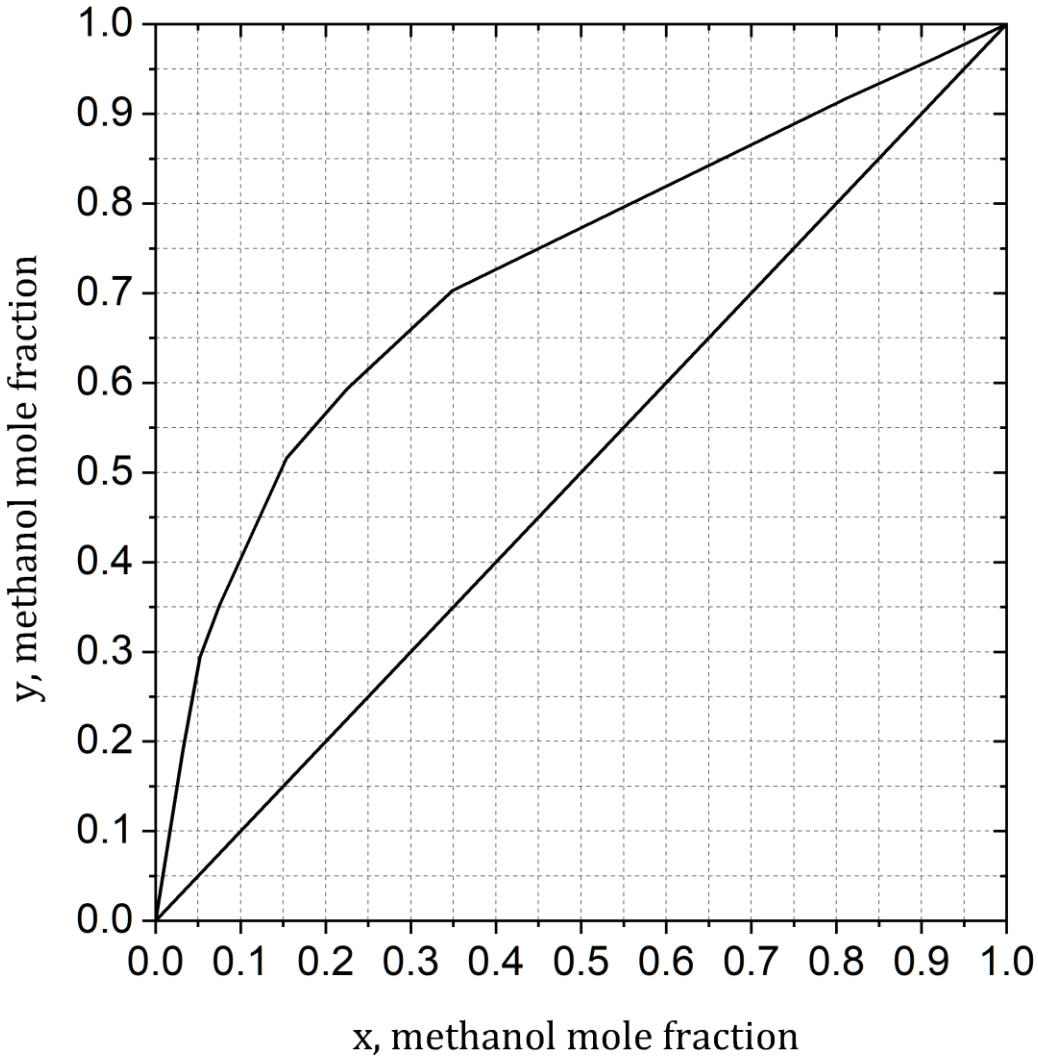
(c) **(6pts)** If the feed enters the column with a 50% vaporized fraction. Determine the total number of theoretical stages and the optimal feed stage number.



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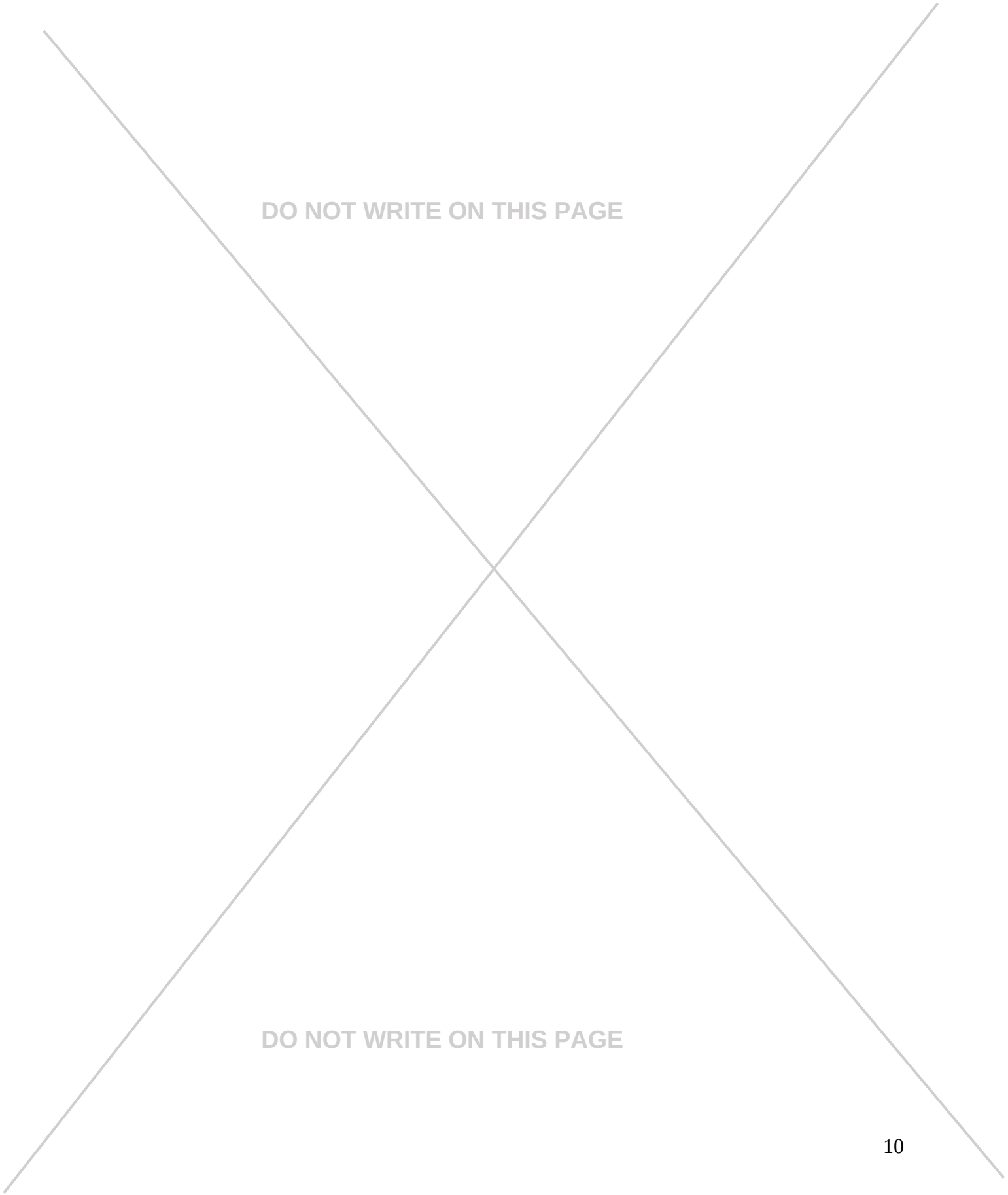

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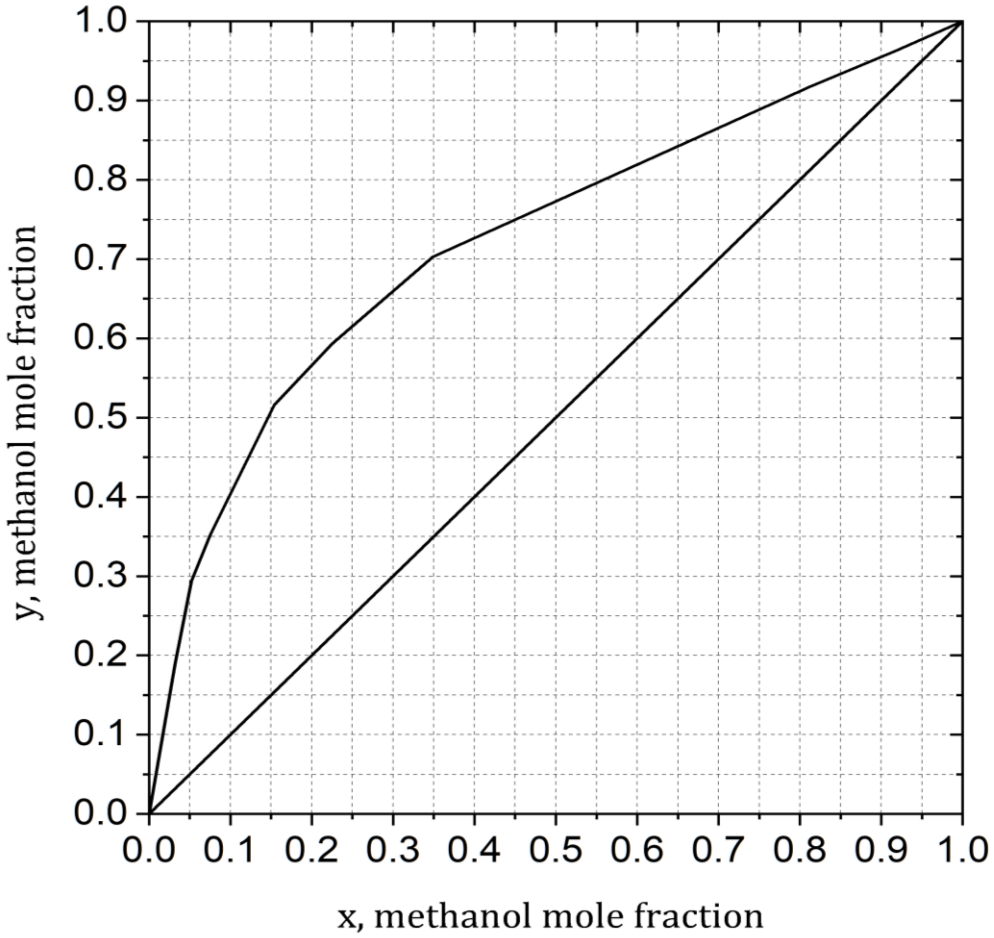
(d) **(6pts)** You inspect the column and confirm that all plates are functioning well and the feed is entering at the optimal location. However, different data is reported in Table 2 for the abnormal operation. Based on Table 2, estimate the vaporized fraction (in percent) of the feed using the figure below.

Stream	molar flow rate (kmol/h)	methanol fraction (mol%)
Feed (F)	100	50
Bottoms (B)	43.75	5
Distillate (D)	56.25	85
Overhead vapor (V)	112.5	
Boilup vapor ($\bar{V}$)	43.75	

Table 2. Table 1. Records of the abnormal operation



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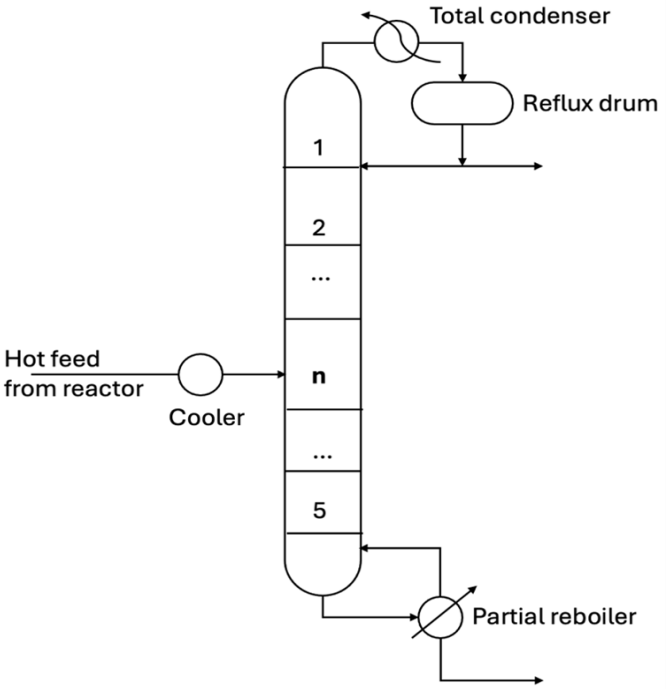
(e) **(3pts)** Compare your result in part (c) and (d), circle the part of the schematic where failure most likely occurs and explain with one sentence.



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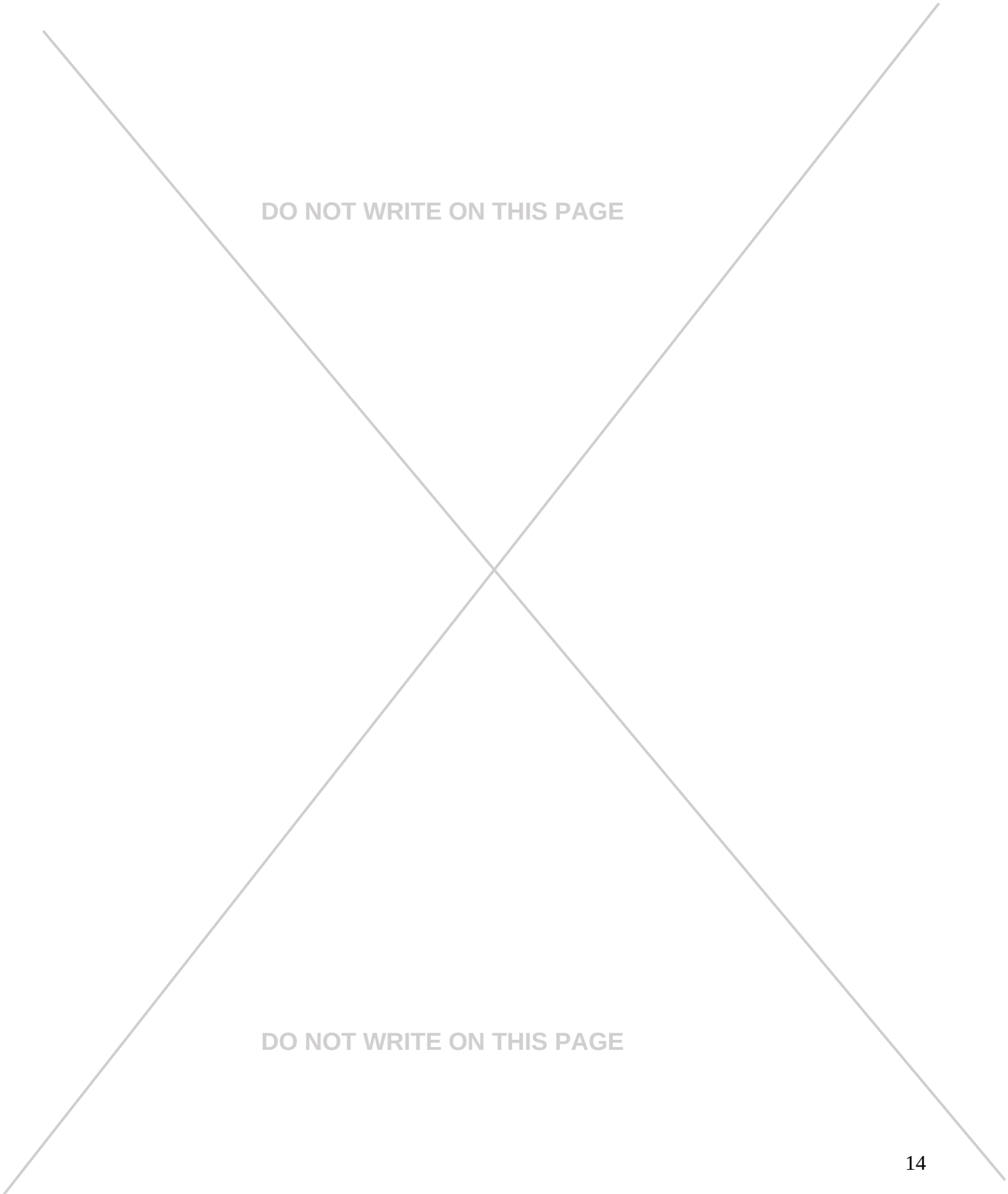

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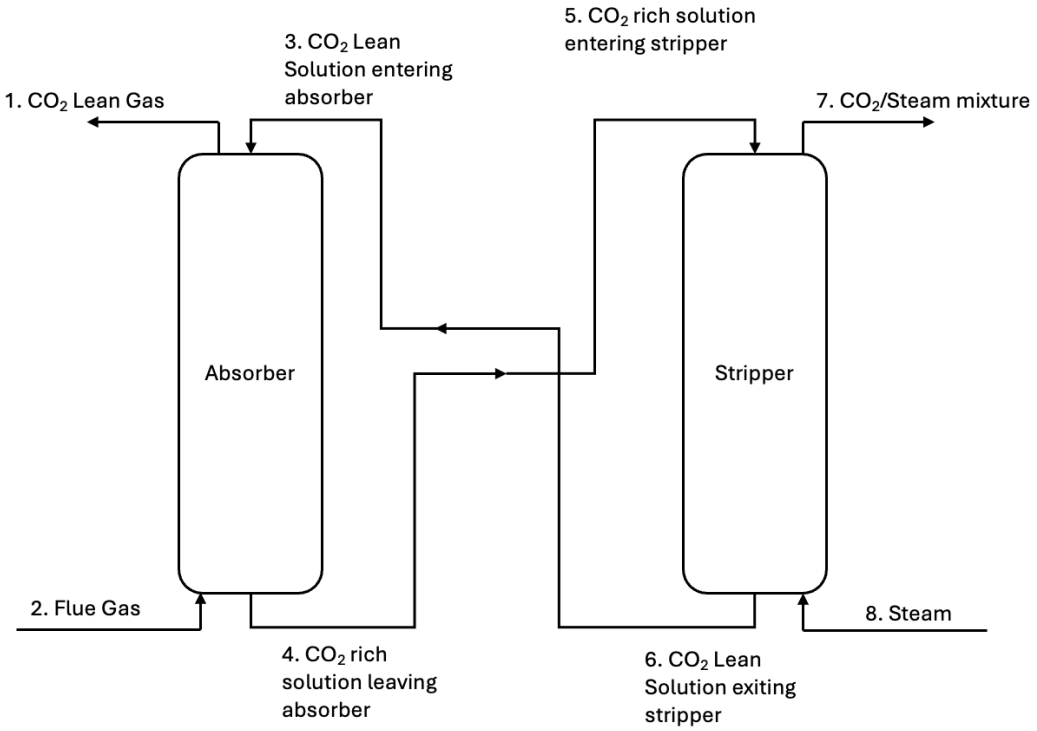
Problem 2 (25pts)

You are tasked to design a carbon capture system that uses an amine solution in the absorber to absorb the CO_2. The Absorber is coupled with a stripper that uses steam to regenerate the absorbant. A set-up is shown below.



Note: Stream 6 and 3 have the same composition & Streams 4 and 5 have the same composition

a) **(4 Pts)** Label streams 1-8 on the Absorber and Stripper (i.e. Y_0, Y_{N+1}, X_1 etc).

Stream	Label
1	
2	
3	
4	
5	
6	
7	
8	

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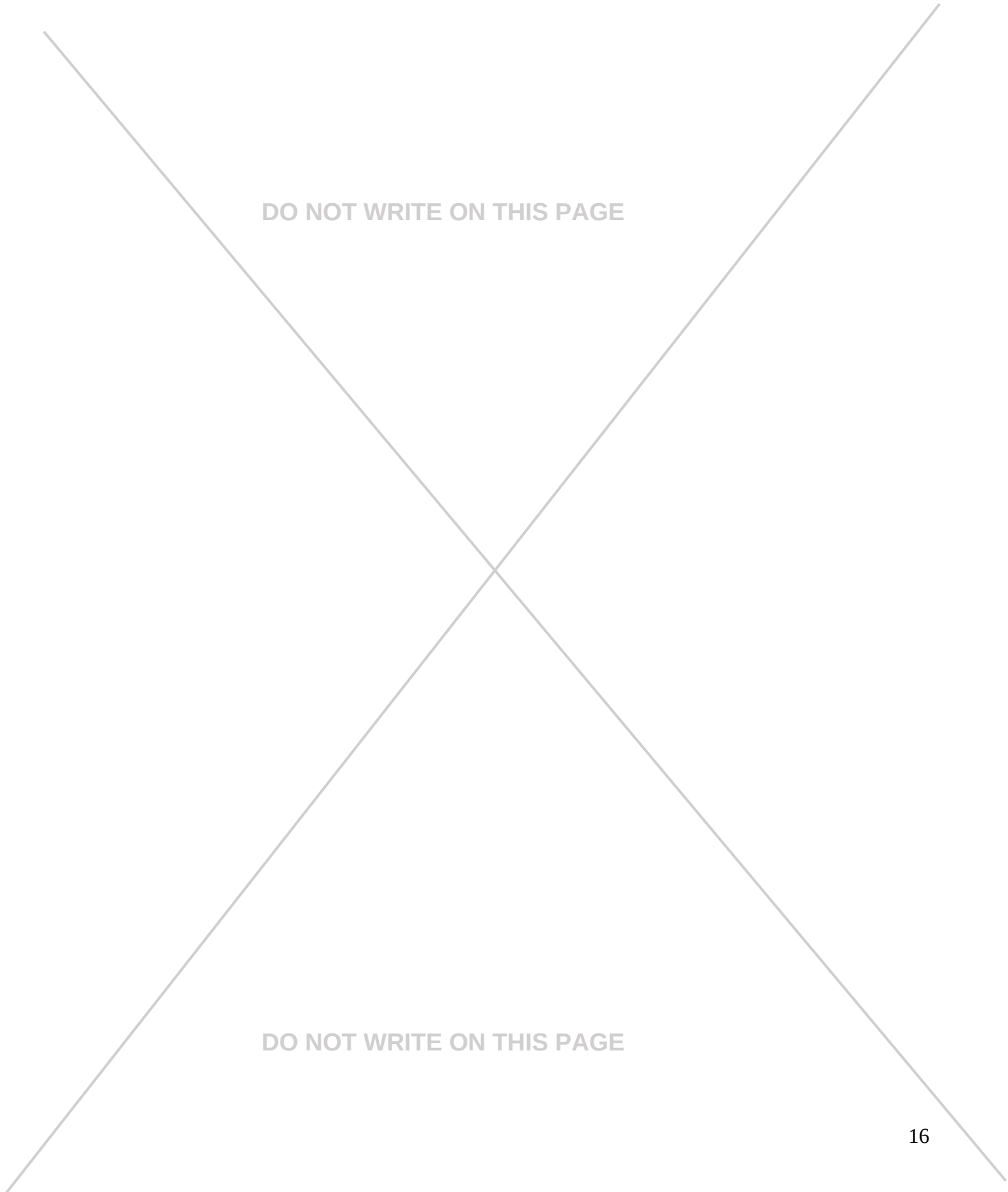

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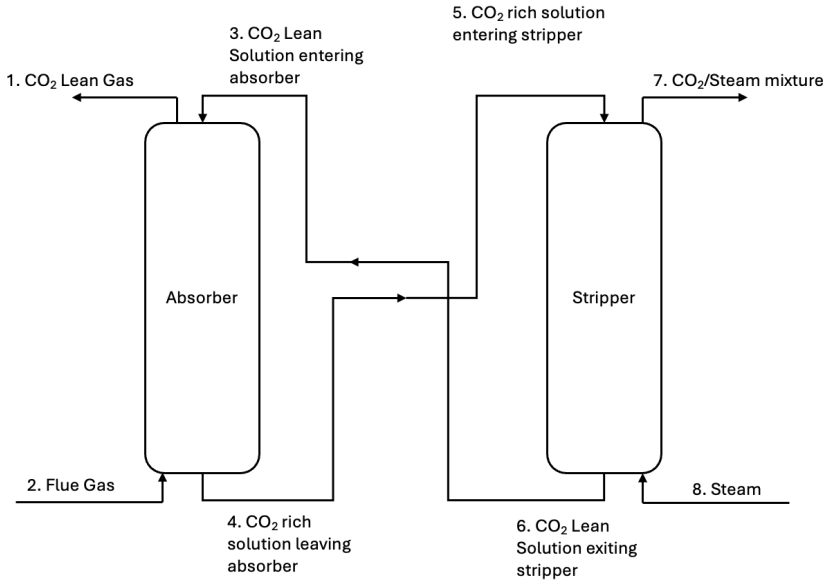
The CO_2 rich gas enters the absorber with 14.9 mol% (y) CO_2 at a flow rate of 10 kmol/s. The amine solution enters the absorber with a CO_2 concentration of 3.9 mol% (x) at a flow rate of 13.91 kmol/s. The recovery of CO_2 is 71.4%.

b) **(10 pts)** Calculate the mole ratio of CO_2 in the flue gas (stream 2), the CO_2 lean gas (stream 1), the CO_2 lean amine solution (stream 3), and the CO_2 rich amine solution (stream 4).



Note: Stream 6 and 3 have the same composition & Streams 4 and 5 have the same composition

Stream Number	Stream Label (from part A)	Relevant Mole Ratio
Stream 1		
Stream 2		
Stream 3		
Stream 4		

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2b continued)

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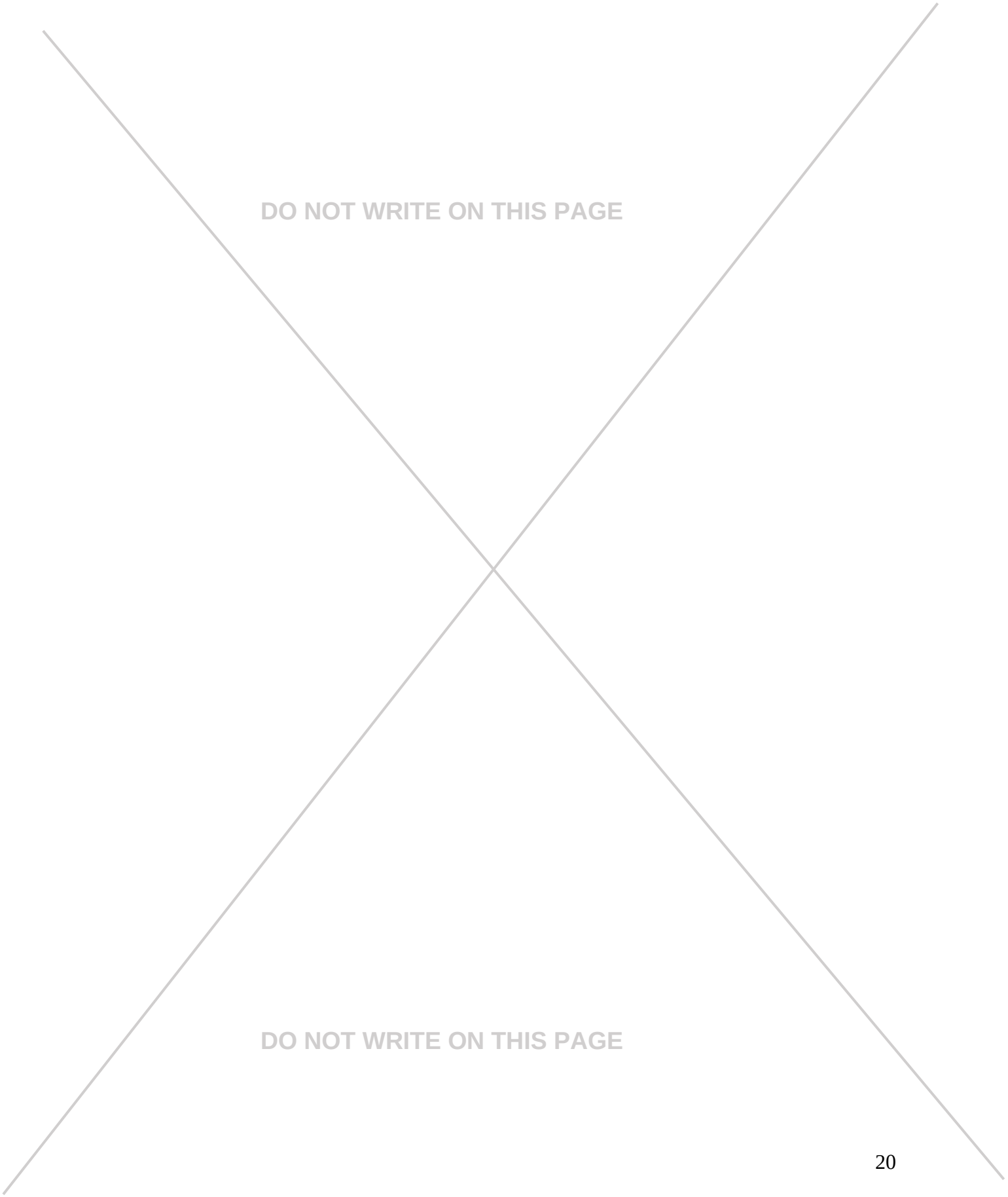

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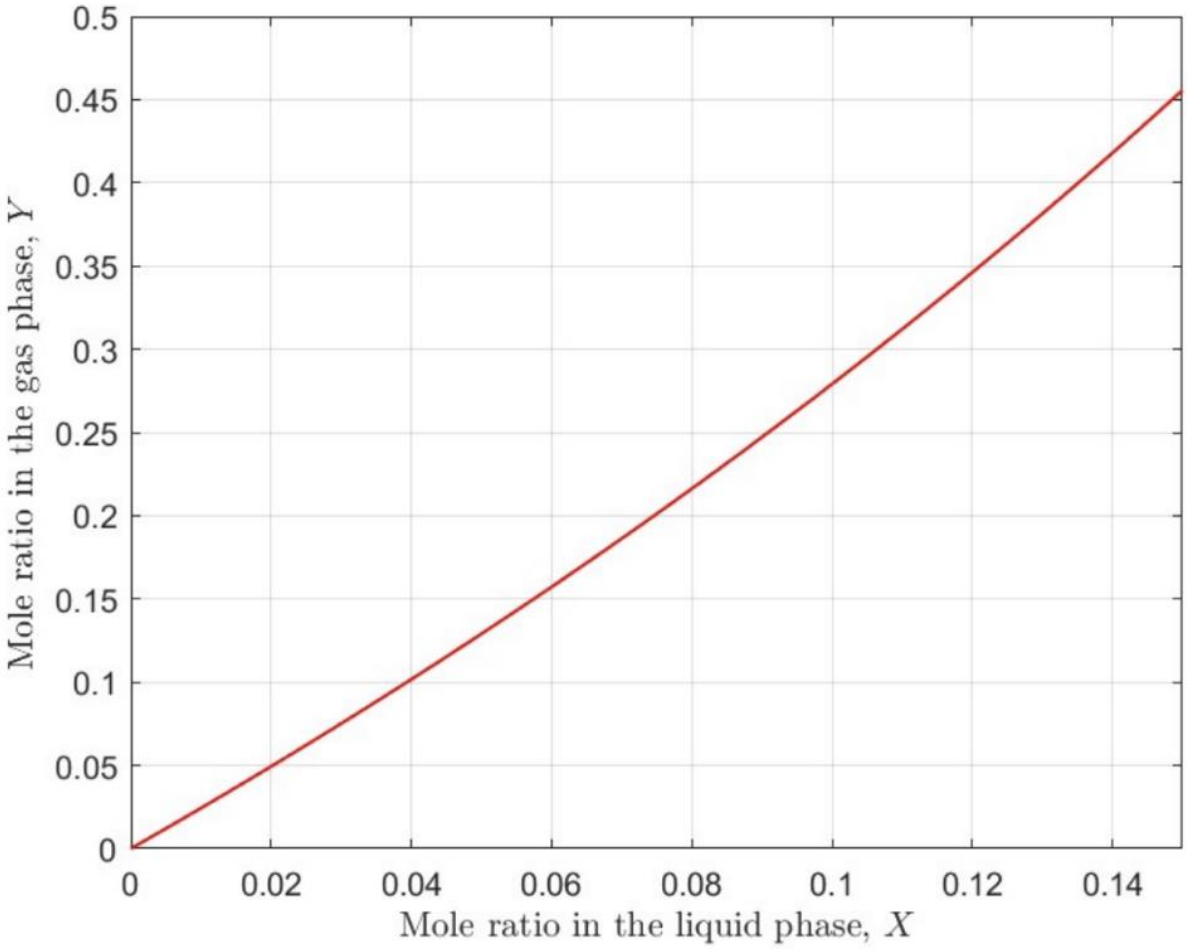
The equilibrium curve for the conditions present in the stripper is given below.

c) **(6Pts)** Determine the minimum amount of (fresh) steam needed to regenerate the amine solution in the stripping column.



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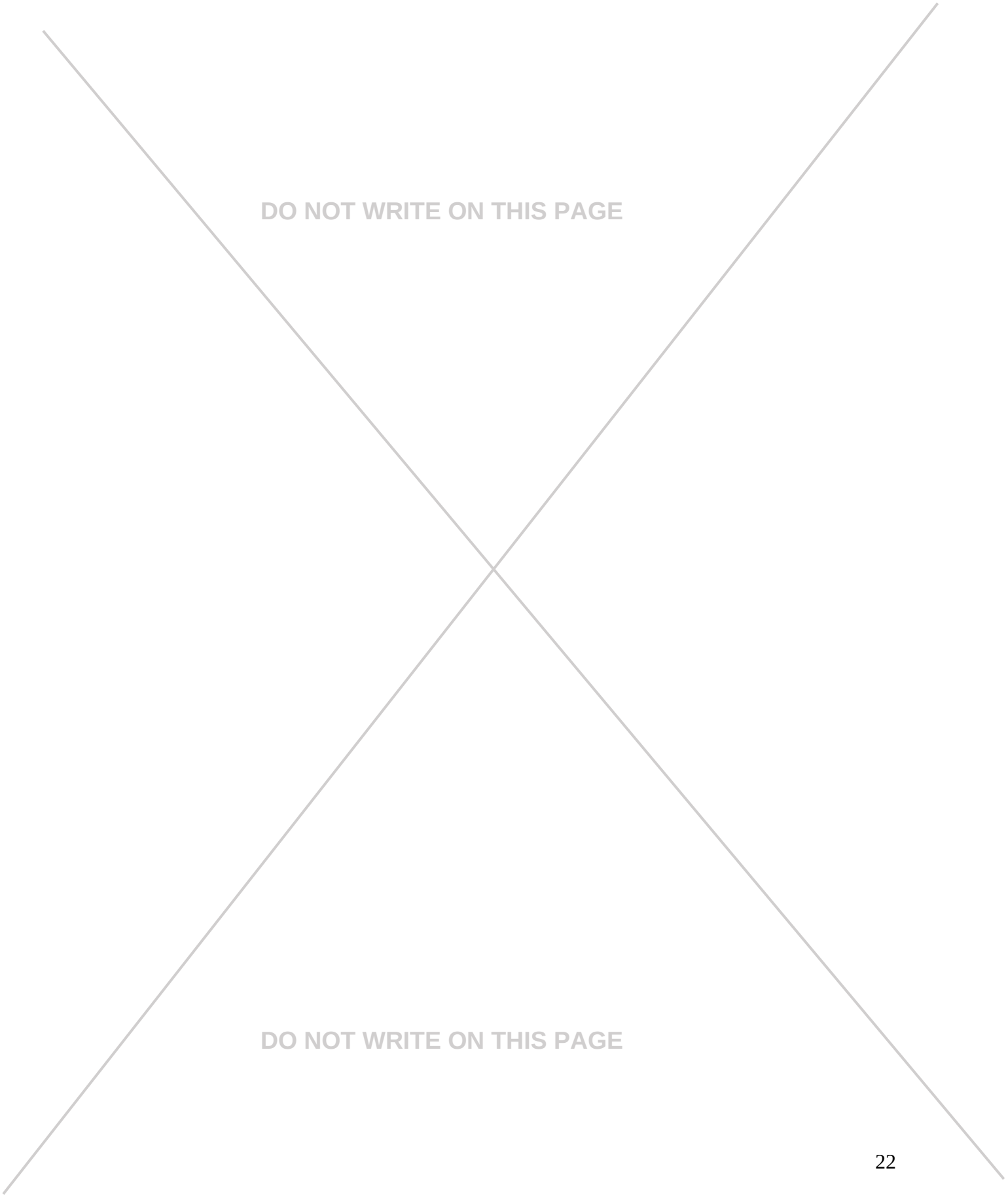

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2c continued)

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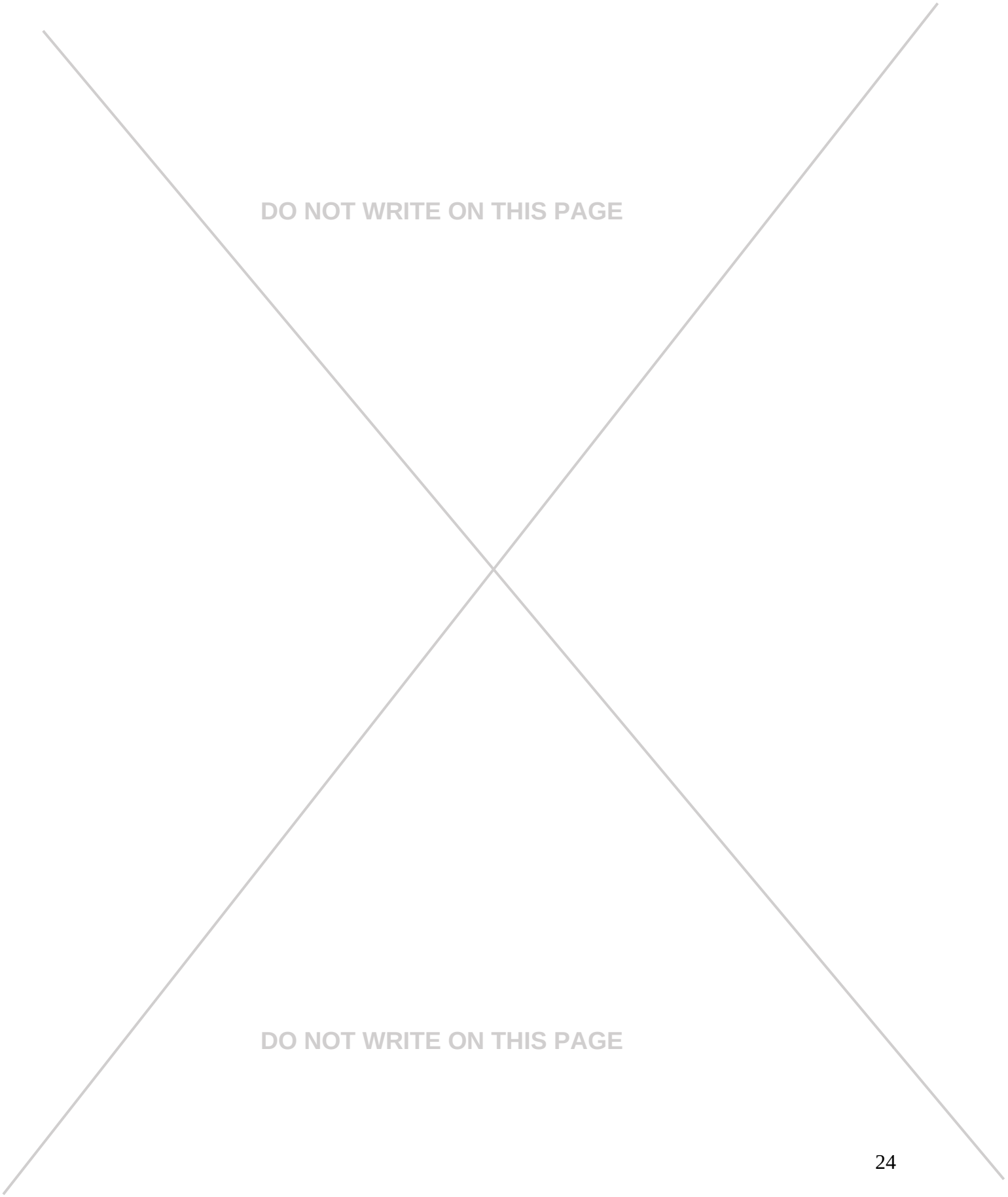

Can be solved without part C.

d) You decide to operate the stripper at a steam flow rate of 3.66 kmol/s. What is the composition of the vapor stream leaving the stripper?

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