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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.

Name (print):____

Name (sign):____

Chemical Engineering 150B

Midterm Exam 2

November 7, 2018

2:10 pm – 3:00 pm

100 Points Total

Four Problems

This examination has 13 pages, including 2 blank pages

Problem 1 _____

Problem 2 _____

Problem 3 _____

Problem 4 _____

Total _________

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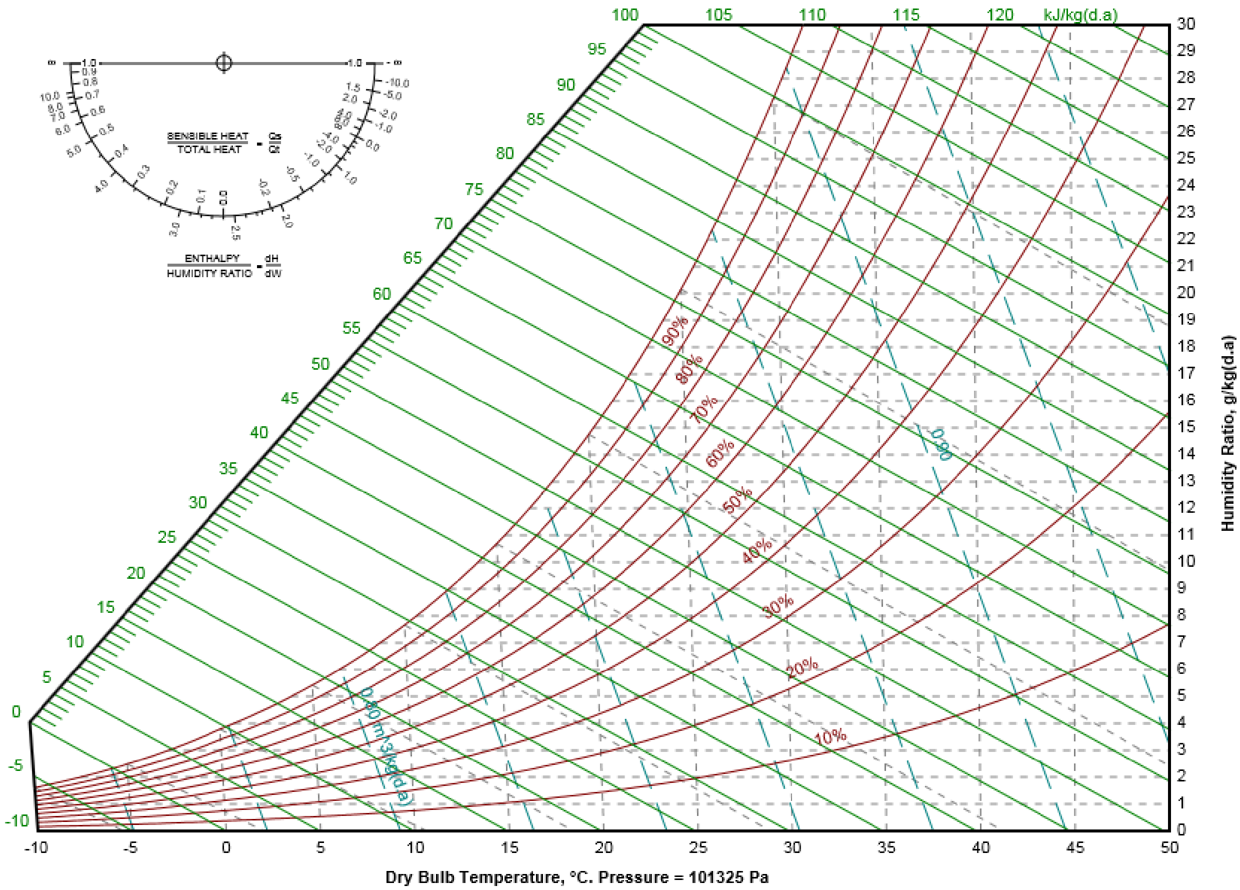
1. **Problem 1. (20 Points)** You plan to dry your wet clothes by hanging them in your room and opening windows on the opposite sides of the room so that air can flow over the clothes. The air enters at 35 °C with a wet bulb temperature of 15 °C. Assume your room is adiabatic, which means that there is no heat flow into or out of the room. Consider only the initial time when the clothes are wet and drying occurs at a constant rate.

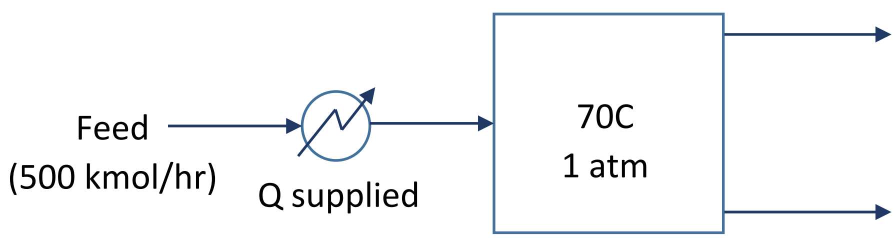


a. (5 points) What is the inlet air humidity in g moisture per kg dry air and RH percentage?

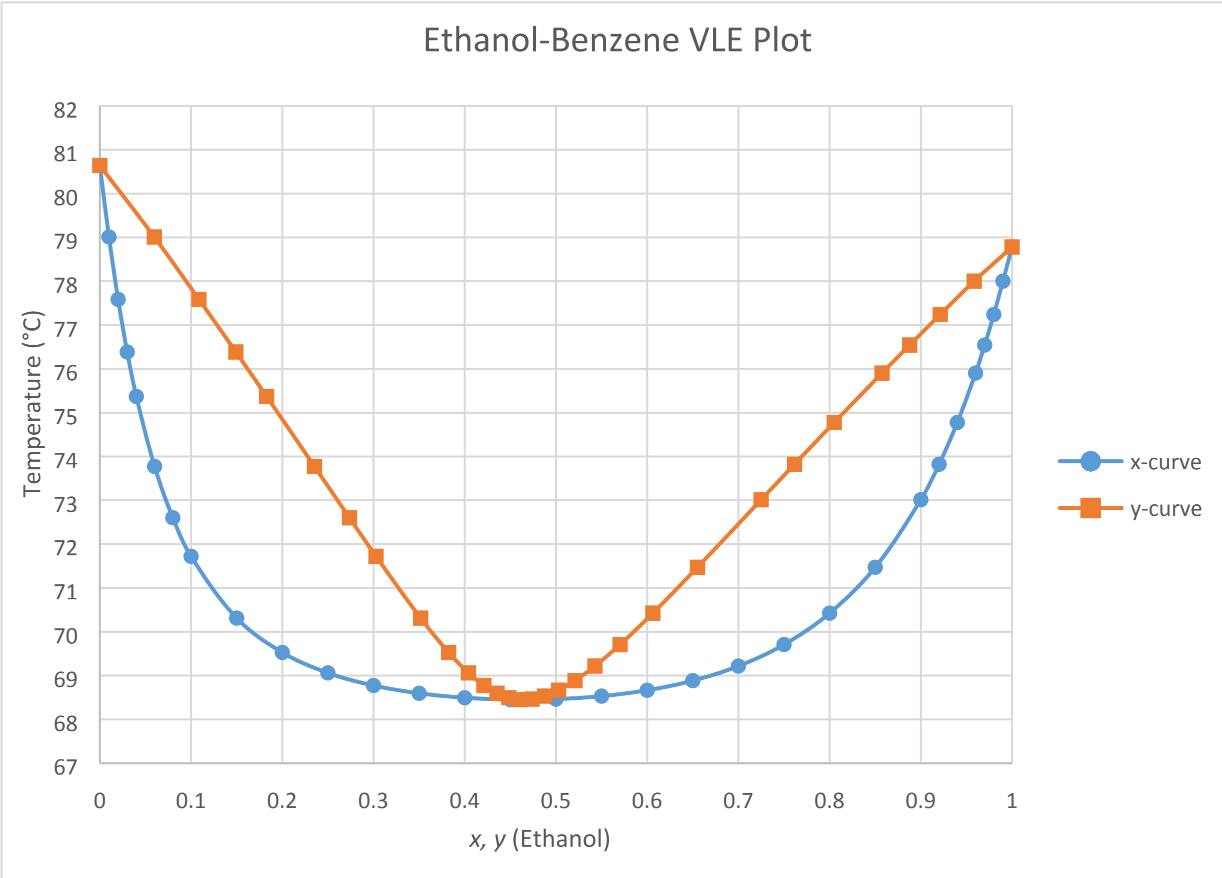
b. (5 points) What will be the equilibrium temperature of the cloth? Explain your answer.

c. (10 points) Calculate the rate of drying. The heat transfer coefficient is h = 62.45 J/s-m^2-K, and the latent heat of vaporization of water at the equilibrium temperature is λ = 2400 kJ/kg.

2. **Problem 2. (30 Points)** An ethanol-benzene mixture containing 30 mol% ethanol undergoes flash distillation at 70 °C and 1 atm, as shown in the figure below. The surroundings are at 27 ˚C.



a. (5 points) What are the feed dew point and bubble point temperatures?



b. (10 points) What are the compositions and flow rates of the exiting vapor and liquid phases?

c. (5 points) What is an azeotrope? At what composition does this mixture behave as an azeotrope?

d. (10 points) Steam at 150 °C is used to transfer Q. Calculate Q and the second-law efficiency of the process given the following information.

	Feed	Vapor	Liquid
Enthalpy (kJ/mol)	18	25	20
Entropy (J/mol-K)	30	42	32

Problem 3. (20 Points) SO_2 contained in air is absorbed into pure water. A column with 6 stages operating at 50% efficiency is used. The feed molar flow rate of the air, which contains $5x10^{-6}$ vol% SO_2, is 100 kmol/h. The molar flow rate of the pure water is 500 kmol/h. The geometric average of the equilibrium constant, K, is 2 at the operating conditions of the column.

a. (5 points) What is the value of the effective absorption factor?

b. (10 points) The EPA requires a maximum SO_2 mole composition in air of $y = 0.075x10^{-6}$ (i.e., 75 ppb). Will the column successfully meet these EPA standards? Briefly explain 2 assumptions used in your calculations.

c. (5 points) Assuming the column always operates at 50% efficiency, explain how you could change at least 3 different parameters to reduce the SO_2 concentration even further.

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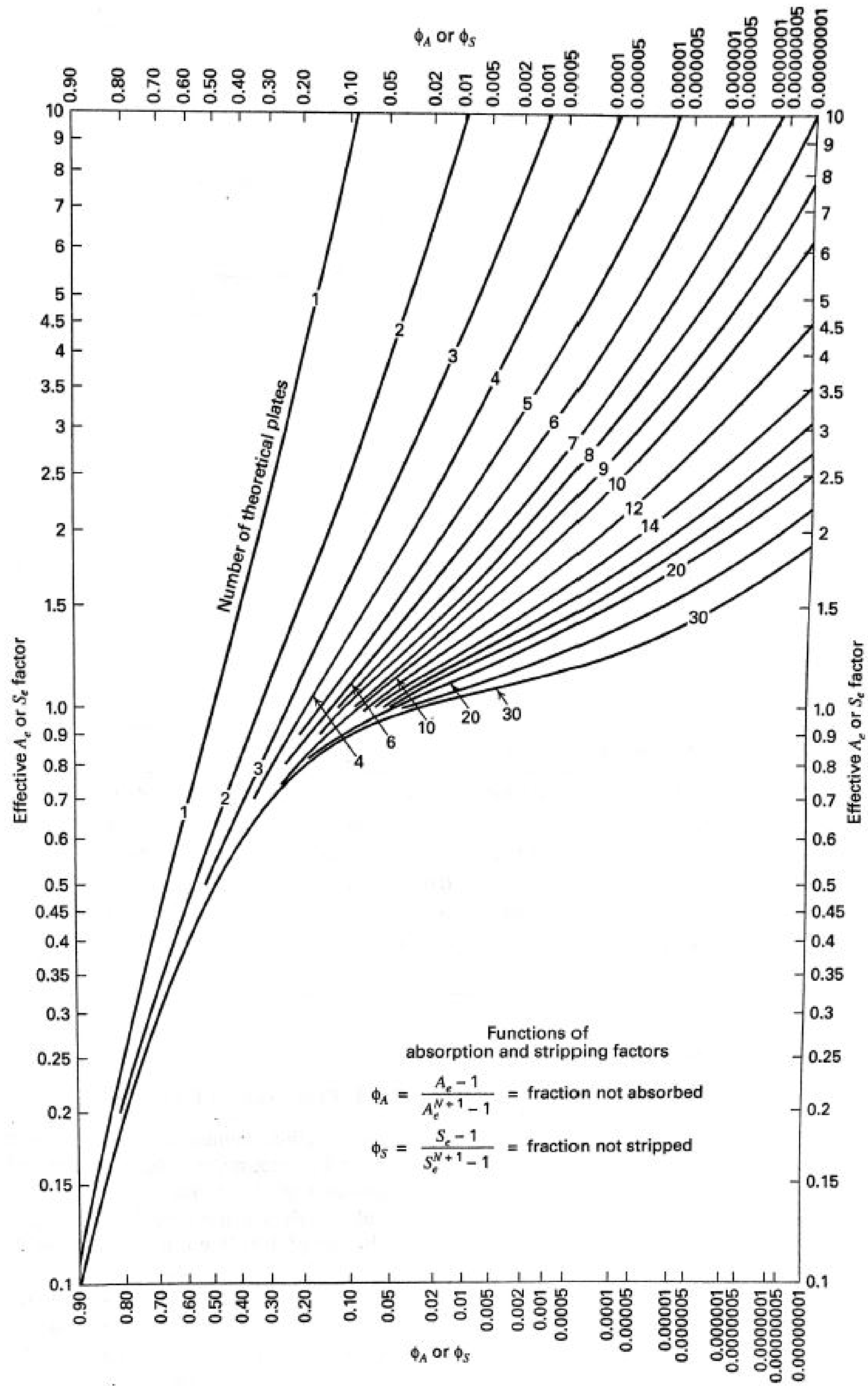
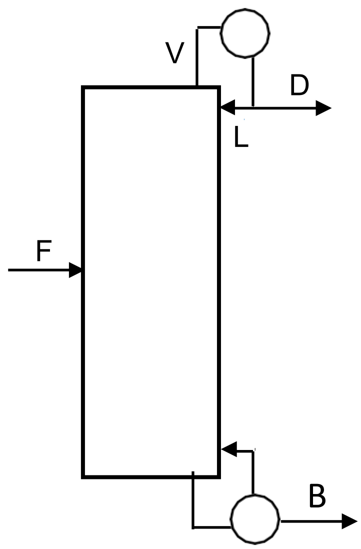


ϕ_A or ϕ_S
Effective A_e or S_e factor
Number of theoretical plates
Functions of absorption and stripping factors
$\phi_A = \dfrac{A_e - 1}{A_e^{N+1} - 1}$ = fraction not absorbed
$\phi_S = \dfrac{S_e - 1}{S_e^{N+1} - 1}$ = fraction not stripped

Problem 4. (30 Points) An equimolar mixture of ethanol and water is fed to a distillation column at a rate of 100 kmol/h. 20% of the feed stream is vapor. You want to recover 90% of the ethanol fed to the column in the distillate, which should have a composition of 80% ethanol. You want to determine which of two reflux ratios is best: $R/R_{min} = 4/3$, or $R/R_{min} = 2$. The operating cost functions, for which the units are \$ per hour of operation, are given by:

$C_{Heat\ Duty} = V * \$1/kmol$ $\quad C_{Stage} = \$10/(stage*h)$



a. (5 pts) Determine D, B, and x_B.

b. (5 pts) Determine R_{min}. Explain your strategy for determining R_{min}.

c. (10 pts) Determine the number of stages and the optimal feed locations for the two reflux ratio options. Use the diagrams (one for each R) below to show how you determine the number of stages for each option, and report the number of stages and the number of the feed stage for each option in the space below.

d. (10 pts) Determine which of the two R/R_{min} options is the least expensive to operate.

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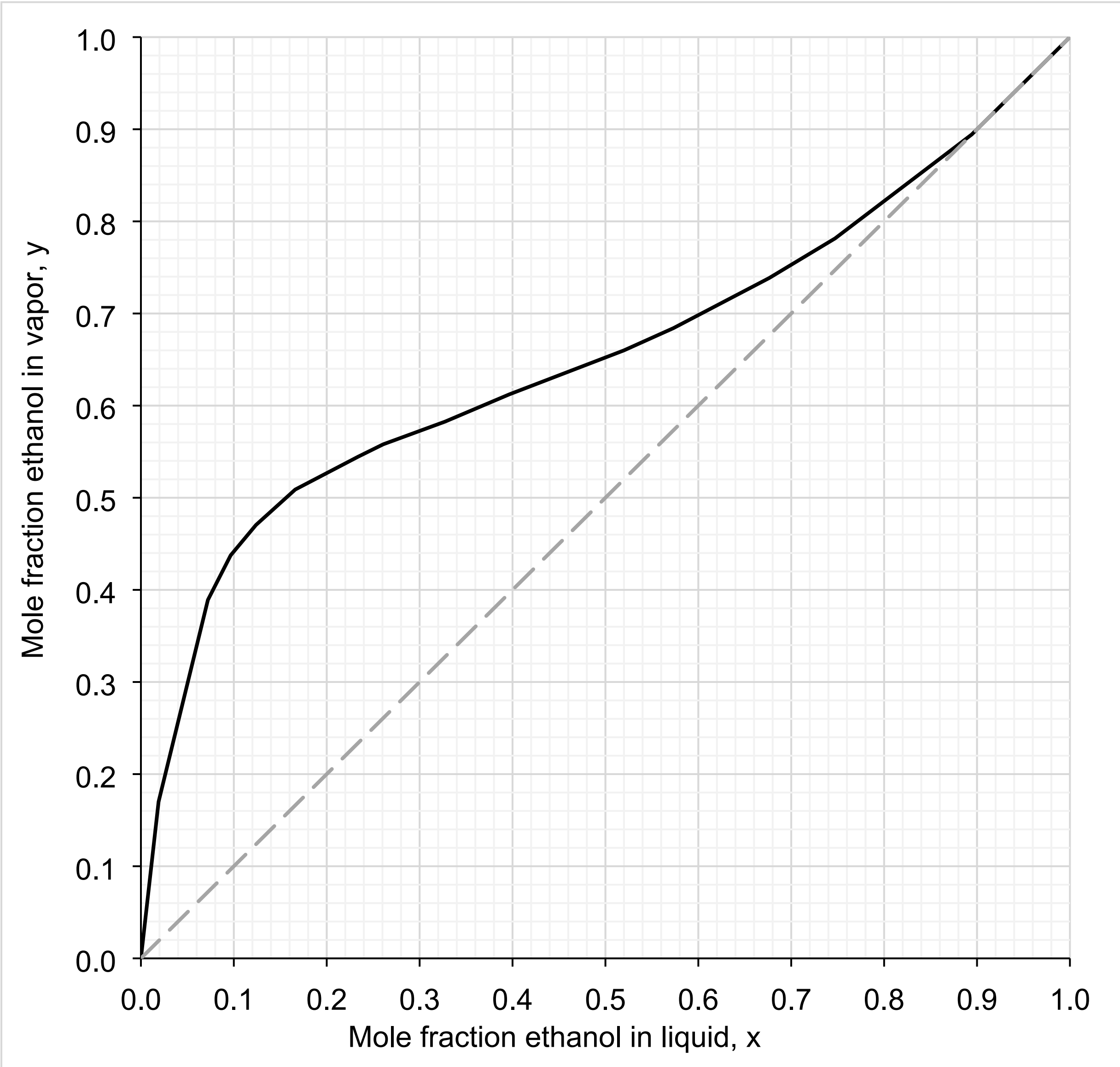

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Mole fraction ethanol in vapor, y
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Mole fraction ethanol in liquid, x

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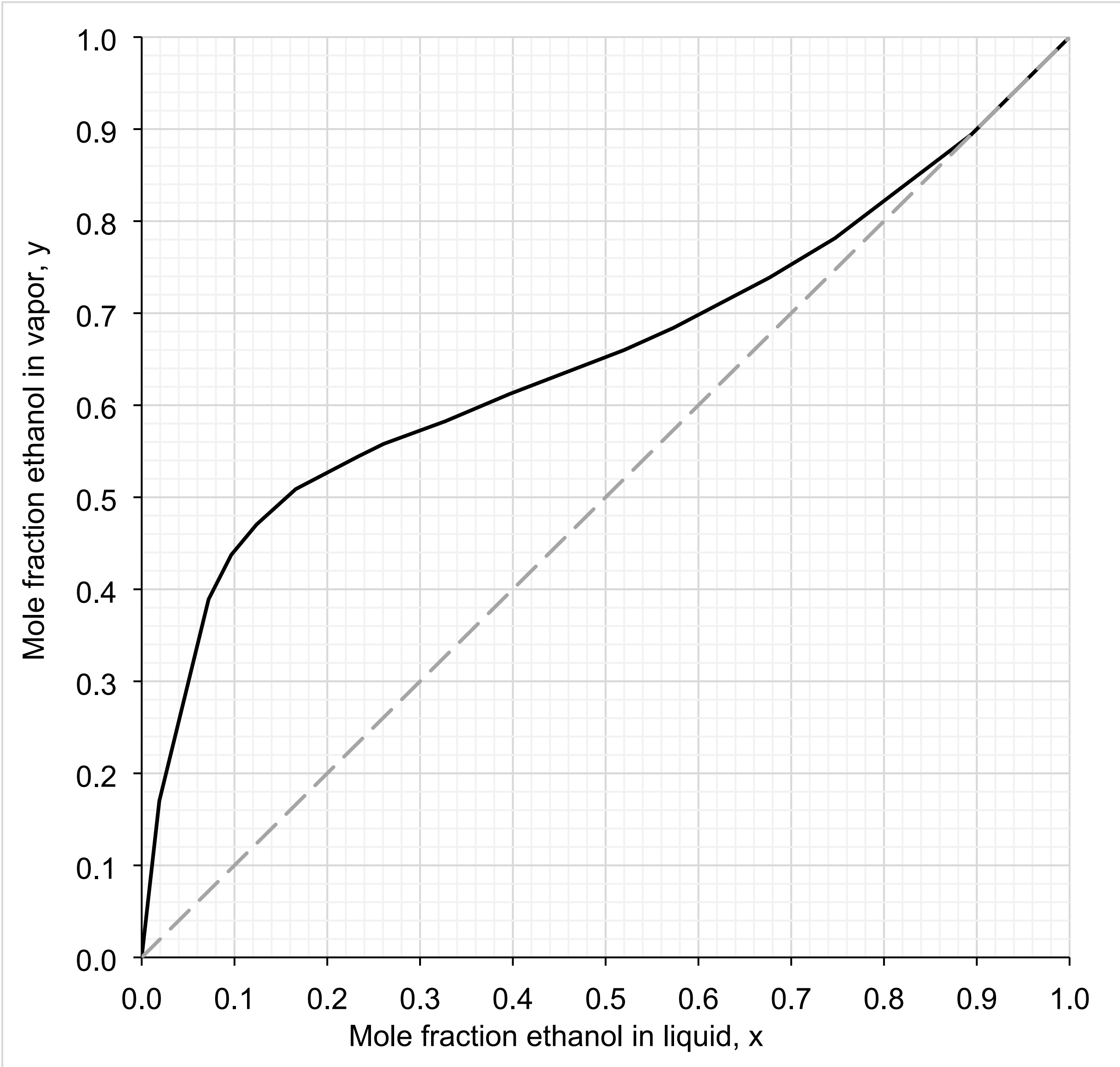

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Mole fraction ethanol in vapor, y
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Mole fraction ethanol in liquid, x

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