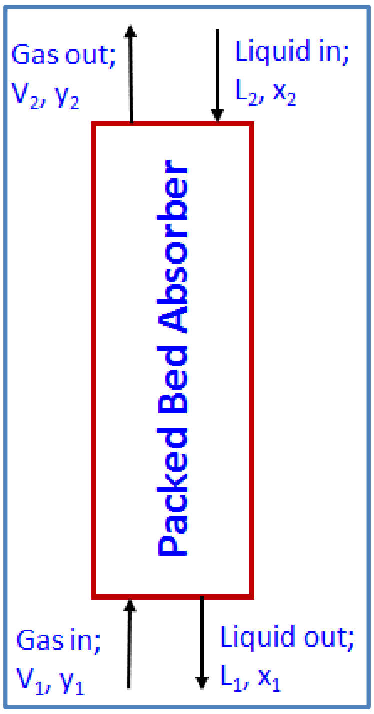
King Saud University
Department of Chemical Engineering
Mass Transfer Operations (CHE 318)
Final Examination

Part 1: Closed Book	May 09 2018	Time Allowed: 30 Min.

Name:	Roll No:

(1+2+3) The figure shows a counter-current packed bed absorber with flow rates and compositions of different streams. Component solute A is being absorbed from gases using liquid (solvent). For the case of absorption, when given $y_1 = 0.05;\ x_2 = 0; slope\ equ.line, m = 10$



Choose the most appropriate answer

(a) $L_1 > L_2$	(b) $L_1 < L_2$
(c) $V_1 < V_2$	(d) None of these is possible

(a) $y_2 = 0.01$	(b) $y_2 = 0.02$
(c) $y_2 = 0.03$	(d) *All of these are possible*

(a) $x_1 = 0.004$	(b) $x_1 = 0.006$
(c) $x_1 = 0.008$	(d) All of these are possible

(4) For a given separation in a counter-current packed bed absorber, if the flow rate of the liquid solvent is decreased, then

(a) x_1 will increase	(b) x_1 will decrease
(c) No effect on x_1	(d) y_1 will decrease

(5) For a given separation in a counter-current packed bed absorber, if x_1, y_1 are in equilibrium, then the absorber

(a) height will be infinite	(b) height will be small
(c) height may be large	(d) Nothing can be said with confidence

(6) For a good separation of component A from a gas mixture of A and B, the solvent should have

(a) low solubility for A and high solubility for B	(b) high solubility for A and low solubility for B
(c) low solubility for A and low solubility for B	(d) high solubility for A and high solubility for B

(7) The value of the minimum solvent rate((L_{min}) for an absorber can be changed by changing

(a) only the temperature not pressure	(b) only the pressure not temperature
(c) either temperature or pressure or both	(d) None of these

(8) A good packing for a packed bed absorber should

(a) high interfacial contact area and high pressure drop	(b) low interfacial contact area and low pressure drop
(c) high interfacial contact area and low pressure drop	(d) low interfacial contact area and high pressure drop

(9) The gas velocity in the packed bed absorber should be

(a) more than the flooding velocity	(b) less than flooding vel. but above loading point
(c) less than flooding vel. and less than loading point	(d) any gas velocity can be used without any problem

(10) For higher separation in an absorber, one would recommend

(a) high temperature and high pressure	(b) high temperature and low pressure
(c) low temperature and high pressure	(d) low temperature and low pressure

(11) In the design of the absorber, if the thermodynamic data is represented as $y = mx$, absorber height (or number of trays) will be highest for

(a) m=2.0	(b) m=1.5

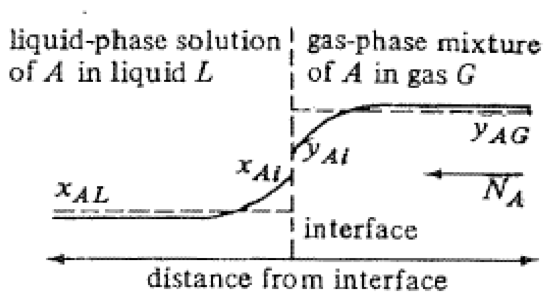
(c) m=1.0	(d) m = 0.5

(12) For diffusion of A through stagnant B, the flux of solute A, N_A , is given by

(a) $N_A = \frac{k'_y}{(1-y_A)_{iM}}(y_{AG} - y_{Ai}) = \frac{k'_x}{(1-x_A)_{iM}}(x_{Ai} - x_{AL})$	(b) $N_A = \frac{K'_y}{(1-y_A)_{*M}}(y_{AG} - y^*_A) = \frac{K'_x}{(1-x_A)_{*M}}(x^*_A - x_{AL})$
(c) both (a) and (b) are correct	(d) both (a) and (b) are incorrect

K'_y: overall gas-phase mass-transfer coefficient in $kg\ mol/s \cdot m^2 \cdot mol\ frac$
K'_x: overall liquid-phase mass-transfer coefficient in $kg\ mol/s \cdot m^2 \cdot mol\ frac$
y^*_A: gas-phase value that would be in equil. with x_{AL}
x^*_A: gas-phase value that would be in equil. with y_{AG}
Subscript '*i*' refers to interface conditions

Conc. profiles of A diffusing through two phases



(13) For the transport of A in a mixture across a gas-liquid interphase, if

$$(y_{AG} - y_{Ai}) \gg (x_{Ai} - x_{AL})$$

this means

(a) gas phase resistance is lower than liquid phase
(b) gas phase resistance is higher than liquid phase
(c) liquid phase driving force is higher than gas phase
(d) low solubility of A in the liquid phase

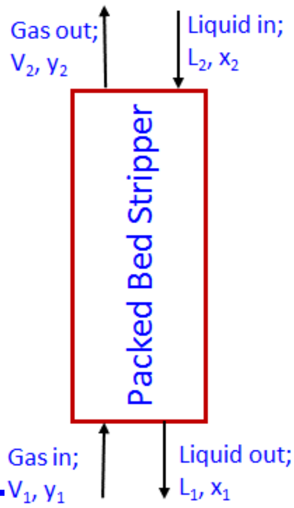
(14) When the major resistance is in gas phase, or the "gas phase is controlling", then

1) $K'_y \cong k'_y$
2) $y_{AG} - y^*_A \cong (y_{AG} - y_{Ai})$
3) $m' = (y_{Ai} - y^*_A)/(x_{Ai} - x_{AL})$ is small

(a) only 1) is correct	(b) both 1) and 2) are correct
(c) all 1), 2) and 3) are correct	(d) none of the above is correct

(15) For the diffusion of gases A and B, the flux of A is given by $N_A = -cD_{AB}\frac{d(x_A)}{dz} + \frac{c_A}{c}(N_A + N_B)$. For the diffusion of gas C through the stagnant non-diffusing gas B, the flux of C (N_C) is given by,

(a)	$-cD_{CB}\frac{d(x_B)}{dz} + \frac{c_B}{c}(N_B)$	(b)	$-cD_{CB}\frac{d(x_B)}{dz} + \frac{c_B}{c}(N_C)$
(c)	$-cD_{BC}\frac{d(x_C)}{dz} + \frac{c_C}{c}(N_C)$	(d)	$-cD_{BC}\frac{d(x_C)}{dz} + \frac{c_C}{c}(N_B)$



(16) For the diffusion of gases A and B, the flux of A is given by $N_A = -cD_{AB}\frac{d(x_A)}{dz} + \frac{c_A}{c}(N_A + N_B)$. For the case of equimolar counter-diffusion,

(a)	$N_A = 0$	(b)	$N_B = 0$
(c)	$N_A = -N_B$	(d)	All of these are incorrect.

(17) In the process of stripping, the solute A is transferred from the liquid stream to the gas stream

(a)	$x_1 > x_2$	(b)	$x_1 < x_2$
(c)	$x_1 = x_2$	(d)	no effect

Answers

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

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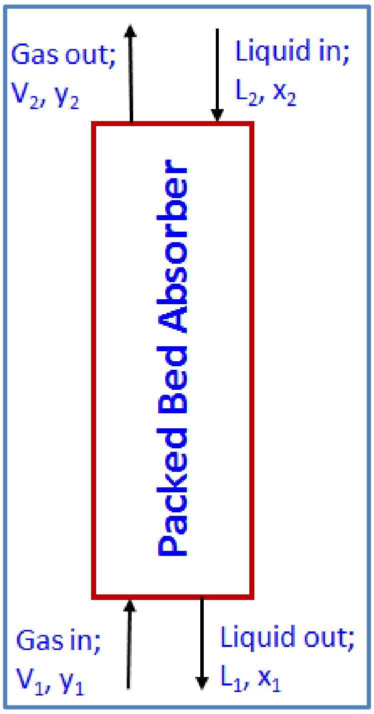
Choose the most appropriate answer



(a)	$L_1 < L_2$	(b)	$L_1 > L_2$
(c)	$V_1 < V_2$	(d)	None of these is possible

(a)	$y_2 = 0.01$	(b)	$y_2 = 0.02$
(c)	$y_2 = 0.03$	(d)	All of these are possible

(a)	$x_1 = 0.006$	(b)	$x_1 = 0.004$
(c)	$x_1 = 0.008$	(d)	All of these are possible

(4) For a given separation in a counter-current packed bed absorber, if the flow rate of the liquid solvent is decreased, then

(a) x_1 will increase	(b) x_1 will decrease
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(5) For a given separation in a counter-current packed bed absorber, if x_1, y_1 are in equilibrium, then the absorber

(a) height will be small	(b) height will be infinite
(c) height may be large	(d) Nothing can be said with confidence

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(c) high temperature and low pressure	(d) high temperature and high pressure

(11) In the design of the absorber, if the thermodynamic data is represented as $y = mx$, absorber height (or number of trays) will be highest for

(a) m=20.0	(b) m=15.0

(c) m=10.0	(d) m = 5.0

(12) For diffusion of A through stagnant B, the flux of solute A, N_A , is given by

(a) $N_A = \frac{k'_y}{(1-y_A)_{iM}}(y_{AG} - y_{Ai}) = \frac{k'_x}{(1-x_A)_{iM}}(x_{Ai} - x_{AL})$	(b) $N_A = \frac{K'_y}{(1-y_A)_{*M}}(y_{AG} - y_A^*) = \frac{K'_x}{(1-x_A)_{*M}}(x_A^* - x_{AL})$
(c) both (a) and (b) are correct	(d) both (a) and (b) are incorrect

K'_y: overall gas-phase mass-transfer coefficient in $kg\ mol/s \cdot m^2 \cdot mol\ frac$
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y_A^*: gas-phase value that would be in equil. with x_{AL}
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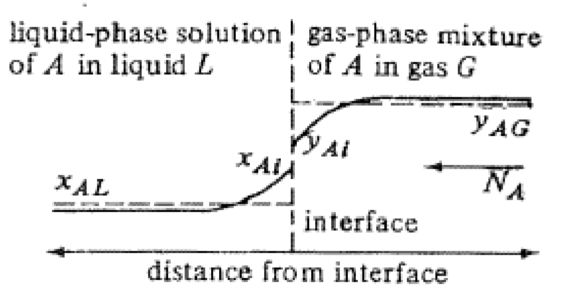
Conc. profiles of A diffusing through two phases



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(a)	$-cD_{CB}\frac{d(x_B)}{dz} + \frac{c_B}{c}(N_B)$	(b)	$-cD_{CB}\frac{d(x_B)}{dz} + \frac{c_B}{c}(N_C)$
(c)	$-cD_{BC}\frac{d(x_C)}{dz} + \frac{c_C}{c}(N_C)$	(d)	$-cD_{BC}\frac{d(x_C)}{dz} + \frac{c_C}{c}(N_B)$

(16) For the diffusion of gases A and B, the flux of A is given by $N_A = -cD_{AB}\frac{d(x_A)}{dz} + \frac{c_A}{c}(N_A + N_B)$. For the case of equimolar counter-diffusion,

(a)	$N_A = -N_B$	(b)	$N_B = 0$
(c)	$N_A = 0$	(d)	All of these are incorrect.

(17) In the process of stripping, the solute A is transferred from the liquid stream to the gas stream

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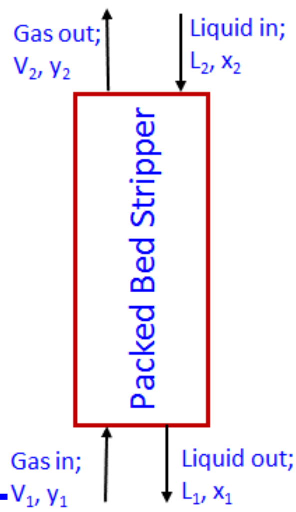

Answers

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Final Part 2: Open Book May 09, 2108 Time Allowed: 2:30 Min.

Name:	Roll No:

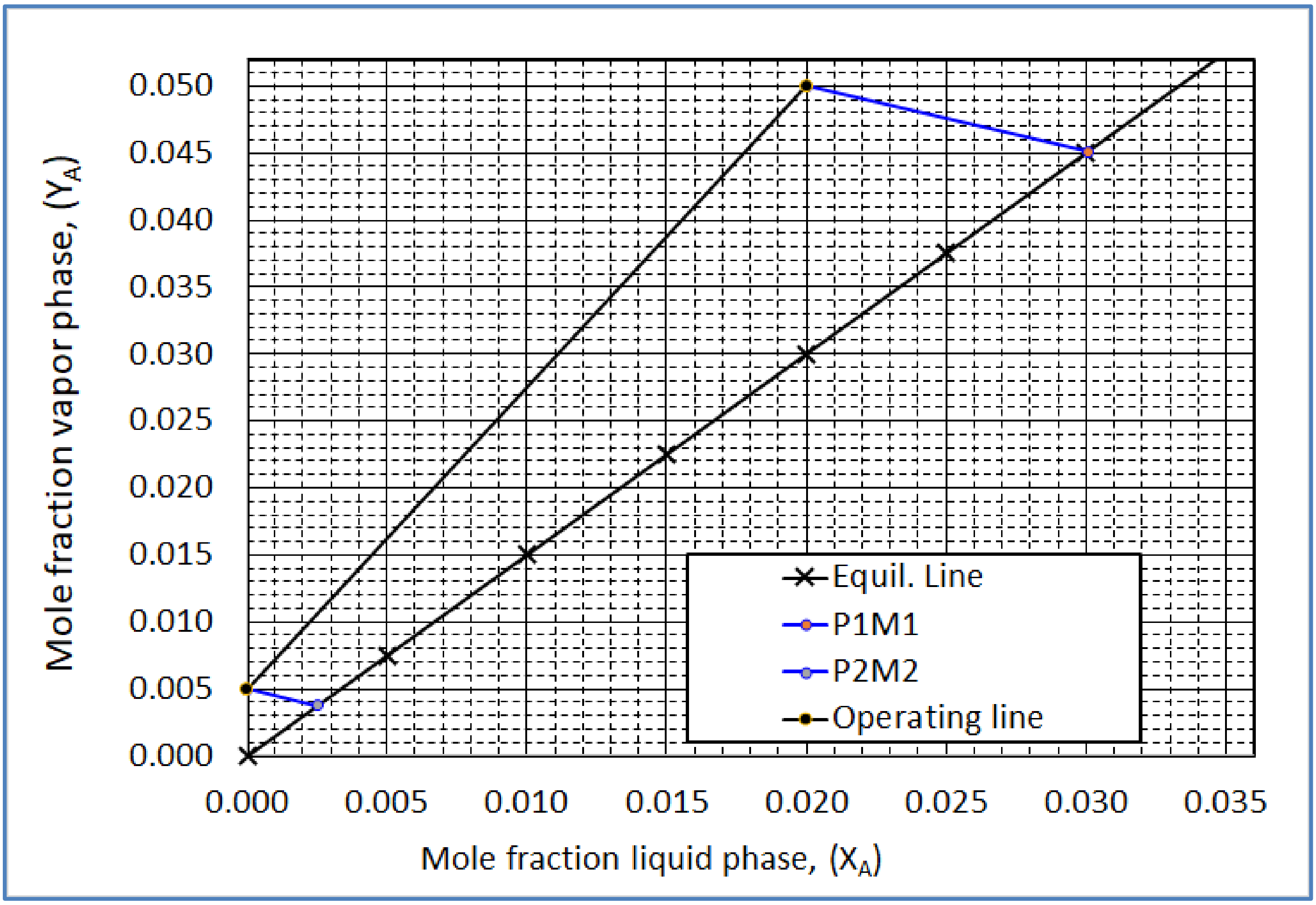
Question 2: (You must show detailed calculations in your answer sheet)

Acetone is being absorbed by water (solvent) in a packed tower having a cross-sectional area of 1 m^2 at 293 K and 101.32 kPa (1 atm). The inlet gas contains $y_1 = 5.0\ mol\%$ acetone and outlet $y_2 = 0.5\ mol\%$. The gas flow is $V' = 1.0\ kg\ \text{mol inert gas/s}$. The pure solvent water ($x_2 = 0\ mol\%$) enters the absorber. Film coefficients for the given flows in the tower are:

$$k'_y a = 2.0 \times 10^{-2} \text{kg mol/s} \cdot \text{m}^3 \cdot \text{mol frac}$$
$$k'_x a = 1.0 \times 10^{-2} \text{kg mol/s} \cdot \text{m}^3 \cdot \text{mol frac}$$

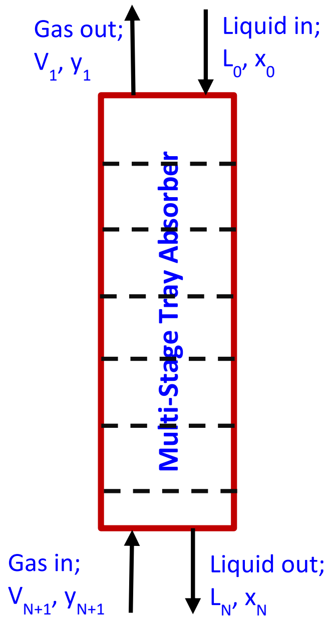
If required, use $(\text{a} = 60\ \text{m}^2/\text{m}^3)$. Using the given figure and the above data, determine

x_{1i}	y_{1i}	x_{2i}	y_{2i}
$(y - y_i)_M$	Absorber height (m)	Slope, m, of equilibrium line	Acetone in the inlet gas (mol/s)
Acetone in the outlet gas (mol/s)	Acetone removed (%)	Flux, N_A, at the tower bottom	Solvent in ($L_2 = ??\ mol/s$)



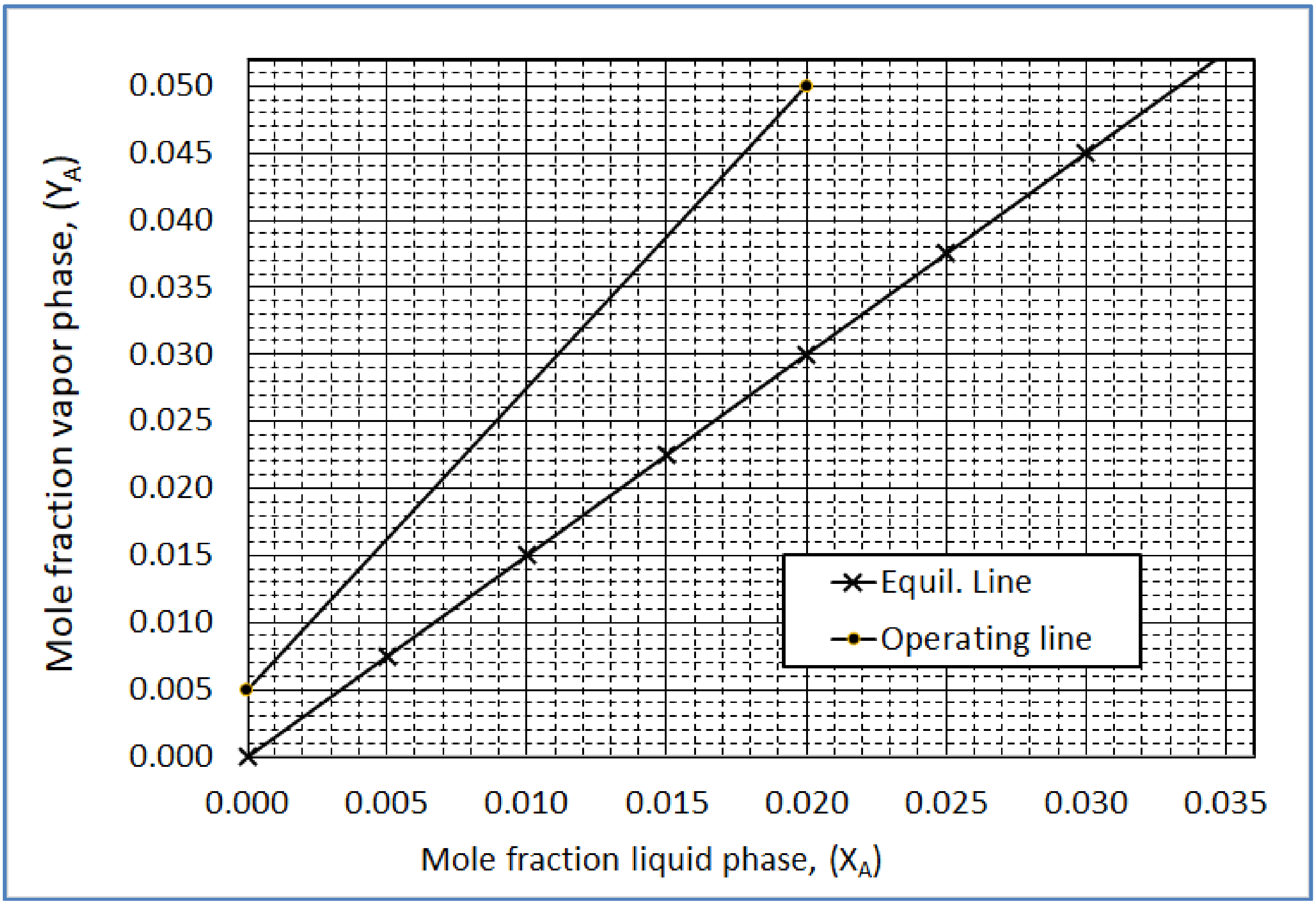
Question 3:

Acetone is being absorbed by water (solvent) in a tray tower having a cross-sectional area of 1 m^2 at 293 K and 101.32 kPa (1 atm). The inlet gas contains $y_{N+1} = 5.0\ mol\%$ acetone and outlet $y_1 = 0.5\ mol\%$. The gas flow is $V' = 10.0$ mol inert gas/s. The pure solvent water ($x_0 = 0\ mol\%$) enters the absorber.



(You must show detailed calculations in your answer sheet)

Number of trays required for separation	Composition of liquid leaving tray 2	Composition of vapor leaving tray 2
Minimum solvent required ($L_{min} = ??\ mol/s$)	Determine the number of ideal stage required for separation using the analytical Kremser equation	



Question 4:

The solute A is being absorbed from a gas mixture of A and B in a wetted-wall tower with the liquid flowing as a film downward along the wall. At a certain point in the tower the bulk gas concentration y_{AG} = 0.30 mol fraction and the bulk liquid concentration is x_{AL} = 0.10. The tower is operating at 298 K and 1013 kPa and the equilibrium data given in the figure. The solute A diffuses through stagnant B in the gas phase and then through a non-diffusing liquid.

Using correlations for dilute solutions in wetted-wall towers, the film mass-transfer coefficient for A in the gas phase is predicted as:

$$k'_x a = 1.0 \times 10^{-2} \text{kg mol/s} \cdot \text{m}^3 \cdot \text{mol frac}$$
$$k'_y a = 5.0 \times 10^{-2} \text{kg mol/s} \cdot \text{m}^3 \cdot \text{mol frac}$$

Compute the slope of the tie lie using

$$-\left[\frac{k'_x a}{(1-x_{AL})}\right] \Big/ \left[\frac{k'_y a}{(1-y_{AG})}\right]$$

If required, assume $a = 10 \text{ m}^2/\text{m}^3$, and answer the following by filling up the table

x_i	y_i	x^*	y^*
$(1-x_i)_M$	$(1-y_i)_M$	$k_x a$	$k_y a$
$K_x a$	Gas film resistance (%)	Liquid film resistance (%)	Molar flux