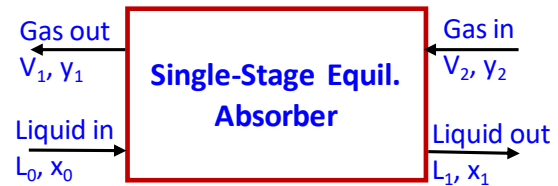


Roll No:	8-10 AM	10 AM-12 Noon
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(1) It is required to separate solute (A) from a gas mixture using a solvent in an absorption process. You have four choices of solvents with different values of the Henry's law constants. Recall that

- $P_A = Hx_A$   
 $P_A$  : Partial pressure of (A) in the gas phase.  
 $H$ : Henry's law constant (atm/mole).  
 $x_A$ : Mole fraction of (A) in the liquid phase.

Figure 1: Equilibrium Single-stage Contacting



Which of the following would you recommend

(a) $H = 10,000 \text{ atm/mole}$	(b) $H = 1,000 \text{ atm/mole}$
(c) $H = 100 \text{ atm/mole}$	(d) $H = 10 \text{ atm/mole}$

(2) For an equilibrium single stage contacting, the following streams are in equilibrium

(a) $L_0$ and $V_1$	(b) $L_0$ and $V_2$
(c) $L_1$ and $V_1$	(d) $L_2$ and $V_2$

(3) If the equilibrium relationship can be represented as  $y = mx = 2x$ , and L-phase ( $L_1$ ) leaving a single-stage equilibrium stage contains 1% solute A, then

(a) $x_0 = 0.02$	(b) $y_2 = 0.5$
(c) $y_1 = 0.02$	(d) $y_1 = 0.05$

(4) In multi-stage absorber design, thermodynamic solubility data are needed for plotting

(a) the equilibrium line only	(b) the operating line only
(c) both operating and equilibrium lines	(d) No need of such data

(5) In the multi-stage counter-current absorber design, (L/V) ratio affects the slope of

- (i) the equilibrium line only  
 (ii) the operating line only  
 (iii) both operating and equilibrium lines

(a) (i) is correct	(b) (ii) is correct
(c) (iii) is correct	(d) None is correct

(6) Since both gas and liquid flowrates are nearly constant for dilute solutions, therefore

(a) operating line is almost straight	(b) operating line is curved
(c) operating line slope is large	(d) operating line slope is small

(7) In the design of the counter-current multi-stage absorber, the number of trays will be infinite, when

(a) $L = L_{min}$	(b) $L \ll L_{min}$
(c) $L < L_{min}$	(d) $L > L_{min}$

(8) If the solvent flow is increased in a counter-current multi-stage absorber, then

(a) $x_N$ will increase	(b) $x_N$ will decrease
(c) $y_{N+1}$ will increase	(d) $y_{N+1}$ will decrease

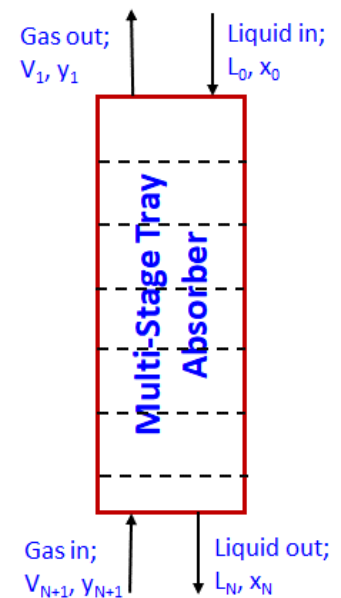
(9) The Knudsen diffusivity of a gas depends upon

- (i) temperature (ii) pressure (iii) molecular weight (iv) capillary radius

(a) (i), (ii) and (iii) are correct	(b) (i), (iii) and (iv) are correct
(c) (i), (ii), (iii) and (iv) are correct	(d) (ii), (iii) and (iv) are correct

(10) The Knudsen diffusion coefficient will be highest for

(a) hydrogen (MW = 2)	(b) nitrogen (MW = 28)
(c) oxygen (MW = 32)	(d) argon (MW = 40)



1	2	3	4	5	6	7	8	9	10
d	c	c	a	b	a	a	b	b	a

Roll No:	8-10 AM	10 AM-12 Noon
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$$P_A = Hx_A$$

$P_A$  : Partial pressure of (A) in the gas phase.

$H$ : Henry's law constant (atm/mole).

$x_A$ : Mole fraction of (A) in the liquid phase.

Which of the following would you recommend

(a) $H = 10,000 \text{ atm/mole}$	(b) $H = 1,000 \text{ atm/mole}$
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(a) $x_0 = 0.02$	(b) $y_2 = 0.5$
(c) $y_1 = 0.02$	(d) $y_1 = 0.05$

(6) In multi-stage absorber design, thermodynamic solubility data are needed for plotting

(a) the equilibrium line only	(b) the operating line only
(c) both operating and equilibrium lines	(d) No need of such data

(7) In the multi-stage counter-current absorber design, ( $L/V$ ) ratio affects the slope of

(i) the equilibrium line only

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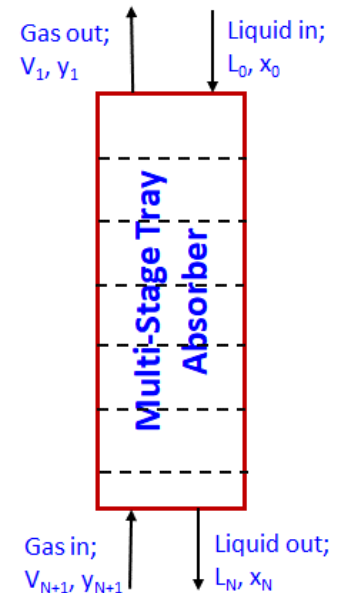
(9) In the design of the counter-current multi-stage absorber, the number of trays will be infinite, when

(a) $L = L_{min}$	(b) $L \ll L_{min}$
(c) $L < L_{min}$	(d) $L > L_{min}$

(10) If the solvent flow is increased in a counter-current multi-stage absorber, then

(a) $x_N$ will increase	(b) $x_N$ will decrease
(c) $y_{N+1}$ will increase	(d) $y_{N+1}$ will decrease

Figure 2: Equilibrium Single-stage Contacting



1	2	3	4	5	6	7	8	9	10
a	b	d	c	c	a	b	a	a	b

## Department of Chemical Engineering

Test 2: Nov 27, 2017

ChE 318

Time: 75 min

Roll Number

- Carry out detailed calculations in answer sheet and provide final answer on this paper
- Open book examination (No notes allowed even if written on the book)

### Question-1

A mixture of He (A;  $MW=4$ ) and Ar (B;  $MW=40$ ) at 298 K is diffusing through an open capillary 15 mm long with a radius of 100 Å. The molecular diffusivity at 1 atm pressure is  $D_{AB} = 7.29 \times 10^{-5} \text{ m}^2/\text{s}$ .

- Calculate the Knudsen diffusivity ( $D_{KA}$ ) of He (A).

$$D_{KA} = 97\bar{r} \sqrt{\frac{T}{M_A}} = 97 \times 100 \times 10^{-10} \sqrt{\frac{298}{4}} = 8.4 \times 10^{-6} \text{ m}^2/\text{s}$$

- Calculate diffusivity ( $D''_{NA}$ ) if  $x_{A1} = 1.0$  and  $x_{A2} = 0.0$  at a total pressure of 1 atm

$$\alpha = 1 - \left(\frac{M_A}{M_B}\right)^{0.5} = 1 - \left(\frac{4}{40}\right)^{0.5} = 0.68377$$

$$D''_{NA} = \frac{1}{(1 - \alpha x_{av})/D_{AB} + 1/D_{KA}} = \frac{1}{(1 - 0.684 \times 0.5)/7.29 \times 10^{-5} + 1/8.4 \times 10^{-6}} = 7.78 \times 10^{-6} \text{ m}^2/\text{s}$$

- Calculate diffusivity ( $D''_{NA}$ ) if  $x_{A1} = 1.0$  and  $x_{A2} = 0.0$  at a total pressure of 0.1 atm

$$D''_{NA} = \frac{1}{(1 - \alpha x_{av})/D_{AB} + 1/D_{KA}} = \frac{1}{(1 - 0.684 \times 0.5)/7.29 \times 10^{-4} + 1/8.4 \times 10^{-6}} = 8.3 \times 10^{-6} \text{ m}^2/\text{s}$$

### Question-2:

An inlet air stream entering a counter-current absorption tower contains 2 mol% acetone vapor. It is required to remove the 90% acetone using liquid water as solvent. The total inlet air flow is 50 kg mol/h, and the total inlet pure water flow is 150 kg mol/h. The process is to operate isothermally at 293 K and a total pressure of 101.32 kPa. The equilibrium relation for the acetone (A) can be assumed to be  $y_A = 2x_A$

- Determine the flow rate and composition of the solvent leaving the absorber
- Determine the flow rate and composition of the gases leaving the absorber
- Determine the required number of ideal stages. Show the clear sketch on the graph paper using a pencil.
- Determine minimum solvent requirement for given separation using single equilibrium stage.

$P = 101.3 \text{ kPa}; T = 300\text{K};$

$L = \text{Water}; V = \text{Air}; \text{Solure (A)} = \text{Acetone}$

$x_0 = 0.0; y_{N+1} = 0.01$

$L_0 = 150.0; V_{N+1} = 50.0$

**Required: 90% removal of acetone from air**

Acetone in =  $V_{n+1}y_{n+1} = 50.0 \times 0.02 = 1.0$

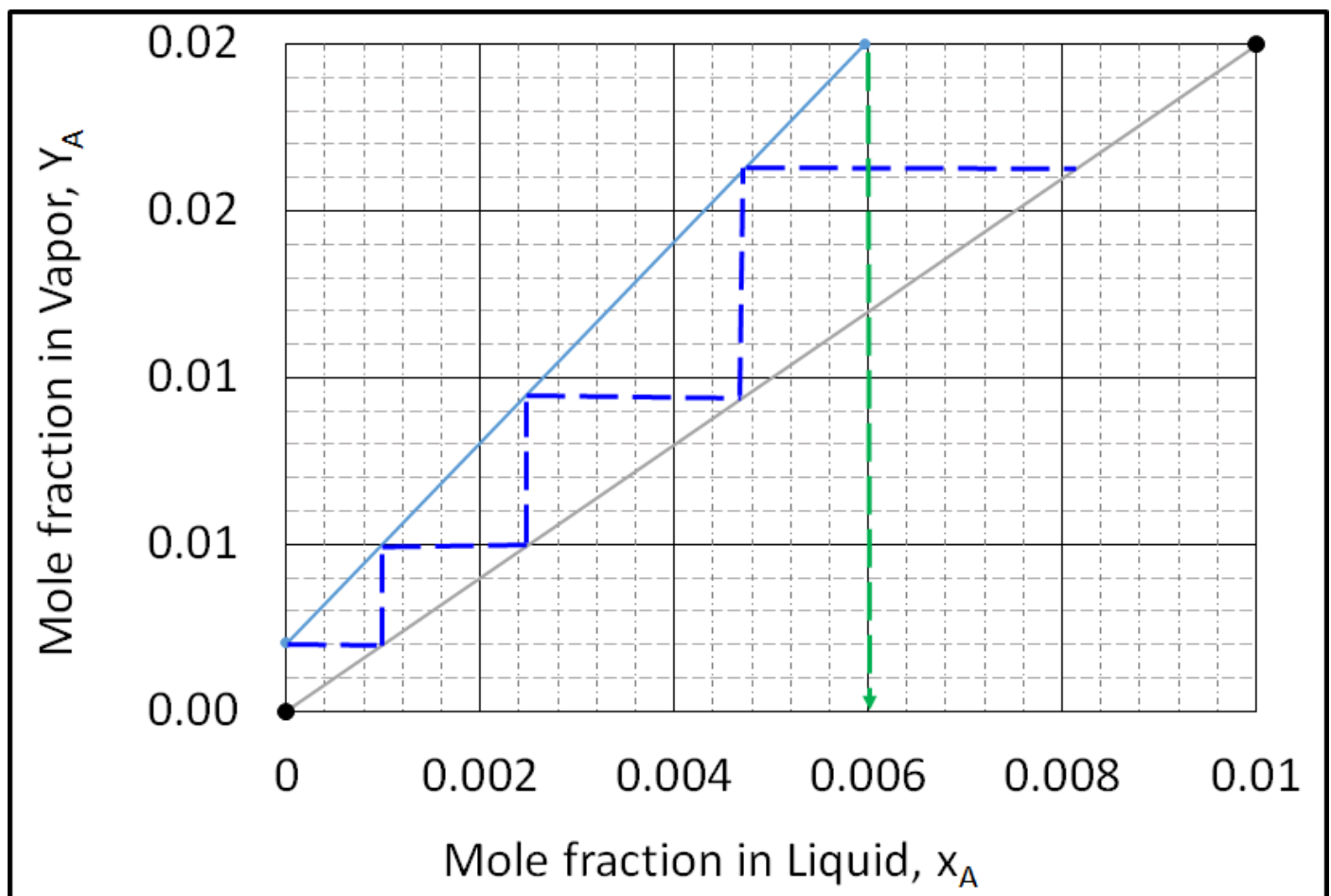
Air in =  $V_{n+1}(1 - y_{n+1}) = 50.0 \times (1 - 0.02) = 49.0$

For 90% removal of acetone from air, Acetone out in  $L_N = 1.0 \times 0.9 = 0.90$

For 90% removal of acetone from air, Acetone out in  $V_1 = 1.0 \times 0.1 = 0.10$

$V_1 = 49 + 0.1 = 49.10; y_1 = \frac{0.10}{49.1} = 0.002$

$L_N = 150 + 0.9 = 150.9; x_{AN} = \frac{0.90}{150.9} = 0.006$



### Question 3:

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. The solute A diffuses through a 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 coefficients for A in the gas and liquid phases are predicted as:

$$k_y = 1.0 \times 10^{-3} \text{ kg mol A/s} \cdot \text{m}^2 \cdot \text{molfrac}$$

$$k_x = 1.0 \times 10^{-3} \text{ kg mol A/s} \cdot \text{m}^2 \cdot \text{molfrac}$$

Note that for dilute solution,  $k'_x = k_x; k'_y = k_y$ .

$x_A$	0	0.050	0.10	0.15	0.20	0.25	0.30
$y_A$	0	0.020	0.050	0.090	0.13	0.19	0.27

At a certain point in the tower, bulk gas concentration is  $y_{AG} = 0.15$  mol fraction and the bulk liquid concentration is  $x_{AL} = 0.05$ . The tower is operating at 298 K and 101.325

kPa and the equilibrium data are given in the table.

Calculate the interface concentration and the flux of component A. Note that you are required to draw the required plot and also show detailed calculations. Make **two trials** to obtain interface concentration. The plot clarity also carries marks.

FIRST TRIAL					
$X_{AL}$	$Y_{AG}$	$X_{Ai}$	$Y_{Ai}$		
0.05	0.15	<b>0.000</b>	0.000		
$1-X_{AL}$	$(1-Y_{AG})$	$1-X_{Ai}$	$1-Y_{Ai}$	$(1-Y_A)_{iM}$	$(1-X_A)_{iM}$
0.95	0.85	1.00	1.00	1.000	1.000
$k'_x$	$k'_y$	$k_x$	$k_y$	Slope(Cal.)	
0.00100	0.00100	0.00100	0.00100	-1.000	

Operating line			
C=y-mx y=mx+C	Point-P	X	Operating Line-1
		0.05	0.15
	Intercept	0.0000	0.2000
		Point	0.1500

SECOND TRIAL					
$X_{AL}$	$Y_{AG}$	$X_{Ai}$	$Y_{Ai}$		
0.05	0.15	<b>0.128</b>	0.072		
$1-X_{AL}$	$(1-Y_{AG})$	$1-X_{Ai}$	$1-Y_{Ai}$	$(1-Y_A)_{iM}$	$(1-X_A)_{iM}$
0.95	0.85	0.87	0.93	0.888	0.910
$k'_x$	$k'_y$	$k_x$	$k_y$	Slope(Cal.)	$N_A = k_x(X_i - X_A)$
0.00100	0.00100	0.00110	0.00113	-0.976	0.00009
					$N_A = k_y(Y_G - Y_i)$
					0.00009

Operating line			
C=y-mx y=mx+C	Point-P	X	Operating Line-2
		0.05	0.15
	Intercept	0.0000	0.1988
		Point	0.2000

