King Saud University
Department of Chemical Engineering
Mass Transfer Operations (CHE 318)
TEST 2

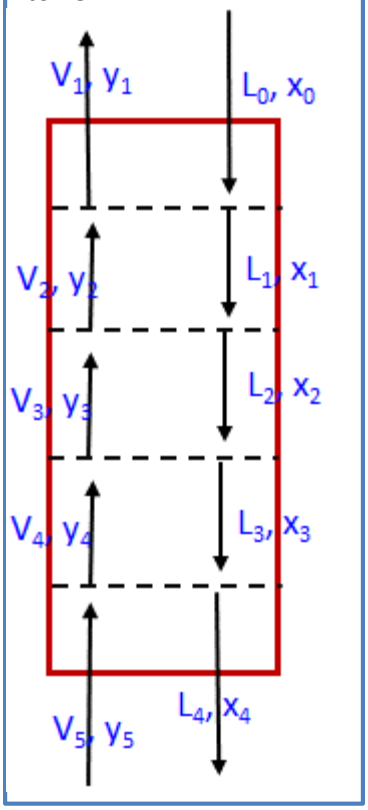
Part 1: Closed Book [33 Marks] Time Allowed: 15 Min.

| Name: | Roll No: |
|---|---|

It is required to separate solute (A) from a gas mixture using a solvent in an absorption process using a multi -tray absorption tower as shown in the figure. There are 4 equilibrium trays/stages required for the given separation. At 1 atm pressure and 298 K, the equilibrium relationship can be represented as:

$y_A = 5x_A$
$y_A$ : Mole fraction (A) in the gas phase (V).
$m = 5$: Henry's law constant (mol frac/mol frac)
$x_A$: Mole fraction (A) in the liquid phase (L).

Fig. 1: Equilibrium multi-stage contacting in tray-tower




(1)

| | |
|---|---|
| (a) $L_0 > L_1$ | (b) $L_0 < L_1$ |
| (c) $L_0 = L_1$ | (d) none of these |

(2)

| | |
|---|---|
| (a) $x_0 > x_1$ | (b) $x_0 < x_1$ |
| (c) $x_0 = x_1$ | (d) none of these |

(3)

| | |
|---|---|
| (a) $V_5 > V_4$ | (b) $y_2 > y_1$ |
| (c) $y_5 > y_2$ | (d) all of these |

(4) If $y_3 = 0.05$, choose one of the following as the best possible

| | |
|---|---|
| (a) $x_3 = 0.25$ | (b) $x_3 \cong 0.05$ |
| (c) $x_3 = 0.0$ | (d) none of these |

(5) If $y_3 = 0.05$, choose one of the following as the best possible

| | |
|---|---|
| (a) $x_2 = 0.010$ | (b) $x_2 = 0.012$ |
| (c) $x_2 = 0.007$ | (d) none of these |

(6) In the given separation shown in the figure, 4 equilibrium stages are required, if the solvent flowrate is increased, it will require (choose one of the following as the best possible)

| | |
|---|---|
| (a) 6 stages | (b) 4 stages |
| (c) 3 stages | (d) no effect |

(7) In the given separation shown in the figure, 4 equilibrium stages are required, if the process temperature is increased to 308 K, it will require (choose one of the following as the best possible)

| | |
|---|---|
| (a) 6 stages | (b) 4 stages |
| (c) 3 stages | (d) all of these are possible |

(8) In the given separation shown in the figure, 4 equilibrium stages are required, if the process pressure is increased, it will require (choose one of the following as the best possible)

| | |
|---|---|
| (a) 6 stages | (b) 4 stages |
| (c) 3 stages | (d) all of these are possible |

(9) In multi-stage absorber design, the change in the temperature and pressure will <u>mainly</u> affect

| | |
|---|---|
| (a) the equilibrium line only | (b) the operating line only |
| (c) both operating and equilibrium lines | (d) no significant effect on both lines |

(10) In the multi-stage counter-current absorber design, the slope of the operating line depends upon

(i) the gas flowrate only
(ii) the liquid flowrate only
(iii) both the gas and liquid flowrates

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

(11) In the multi-stage counter-current absorber design, the slope of the equilibrium line depends upon

(i) the temperature of the process only
(ii) the pressure of the process only
(iii) both the temperature and pressure of the process

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

## Answers

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

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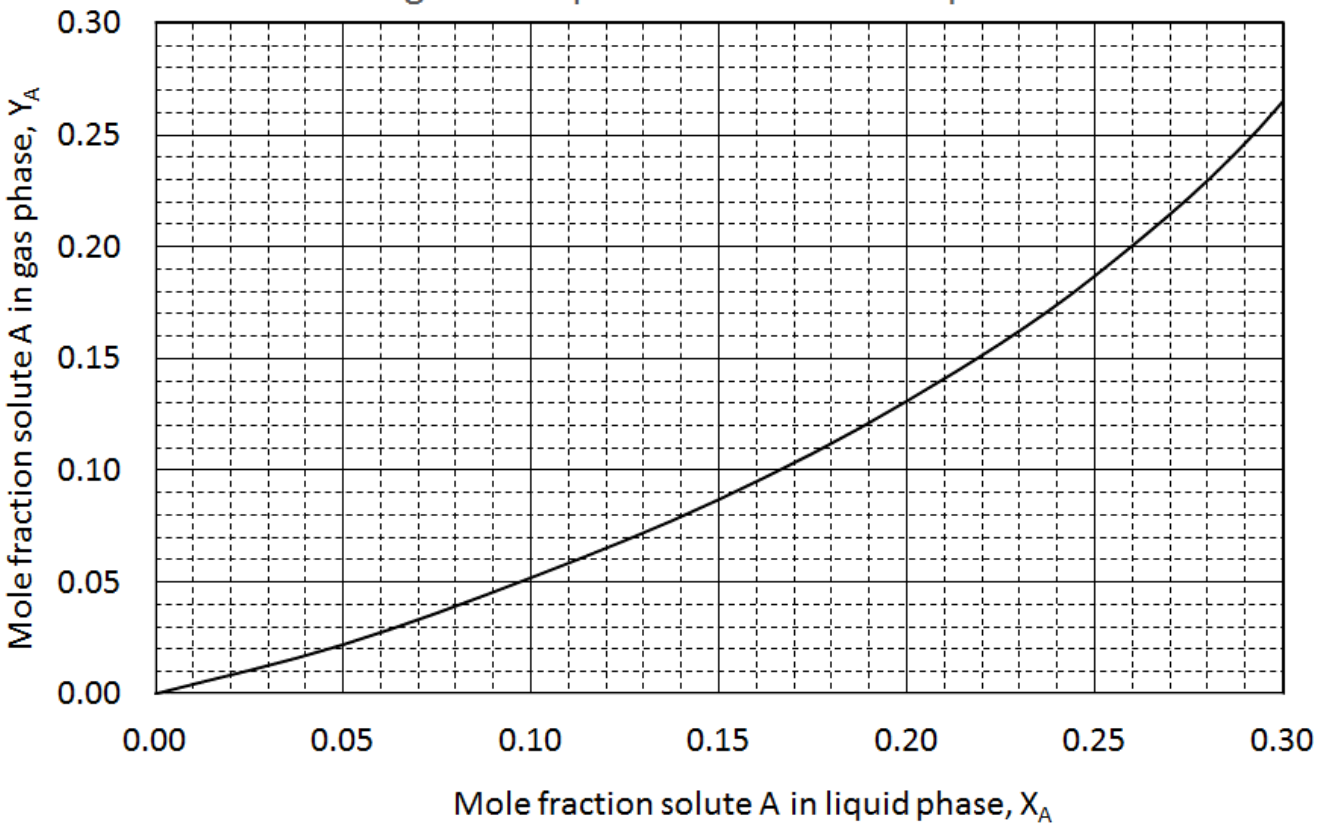
Part 2: Open Book | Time Allowed: 60 min.

| Name: | Roll No: |
|---|---|

## Question 2 [30 pts]:

A tray tower is to be designed to absorb component A from a gas stream by using a solvent. The entering gas contains 25 mol % A and that leaving 2 mol % at a total pressure of 101.3 kPa. The total inlet gas flow rate is 120 kg mol/h.m$^2$, and the flow rate of pure solvent entering is 150 kg mol/h.m$^2$. The process is isothermal at 298 K and 1atm total pressure.

Figure 1: Equilibrium Relationship for Solute A




- From given information in the above figure, determine following stream compositions ( mole fraction for solute A) (Must show calculations where needed)

| Inlet solvent | Outlet solvent | Inlet gas | Outlet gas |
|---|---|---|---|
| | | | |

- Draw operating line assuming it as a straight line. Determine the following (showing a CLEAR sketch in above fig)

| Number of ideal stages | Composition of solvent entering stage 2 | Total amount of solv. entering stage 2 |
|---|---|---|
| | | |

- Determine (Show calculation detailed and clear steps in the answer sheet)

| How much solvent will be required for the required separation of solute A from 25% to 2% from the gas phase, if only one equilibrium stage is used? |
|---|
| |

## Question 3 (Show clear detailed calculations in the Answer sheet) [32 pts]:

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 101.3 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:

$$k'_y = 3.0 \times 10^{-3} \text{kg mol/s} \cdot \text{m}^2 \cdot \text{mol frac}$$

$$k'_x = 6.0 \times 10^{-3} \text{kg mol/s} \cdot \text{m}^2 \cdot \text{mol frac}$$

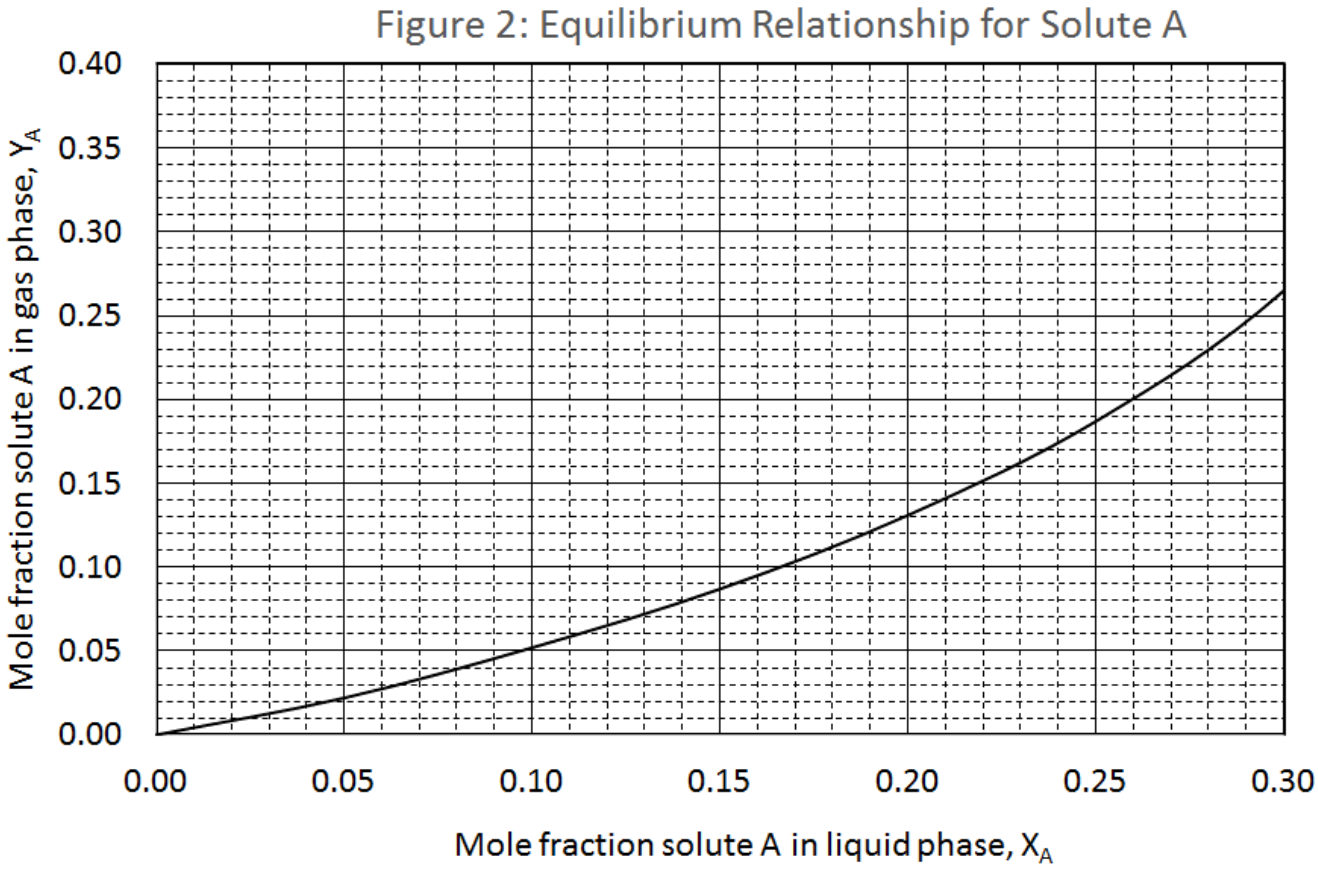
Use the given figure showing the equilibrium line and make only one trial to obtain interface concentration.

- Interface concentrations

| $x_{Ai}$ | $y_{Ai}$ | $(1-y_A)_{iM}$ | $(1-x_A)_{iM}$ |
|---|---|---|---|
| | | | |

- Evaluate

| Molar flux of A using gas phase driving force | $k_x$ /$k_y$ |
|---|---|
| | |




## Question 4 (Show clear detailed calculations in the Answer sheet pts: 5/100):

In Question 2, for the given pure inlet solvent rate of 150 kg mol/h.m$^2$ and total inlet gas flow rate of 120 kg mol/h.m$^2$ (25% solute A), what would be the outlet solvent composition and flow rate, if only one equilibrium stage is used.

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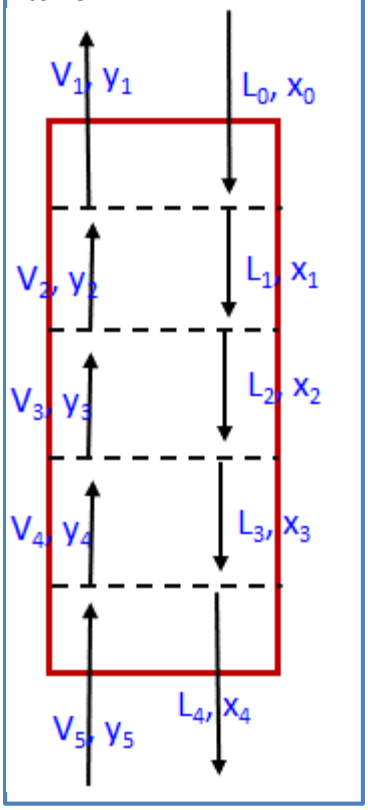
Fig. 2: Equilibrium multi-stage contacting in tray-tower

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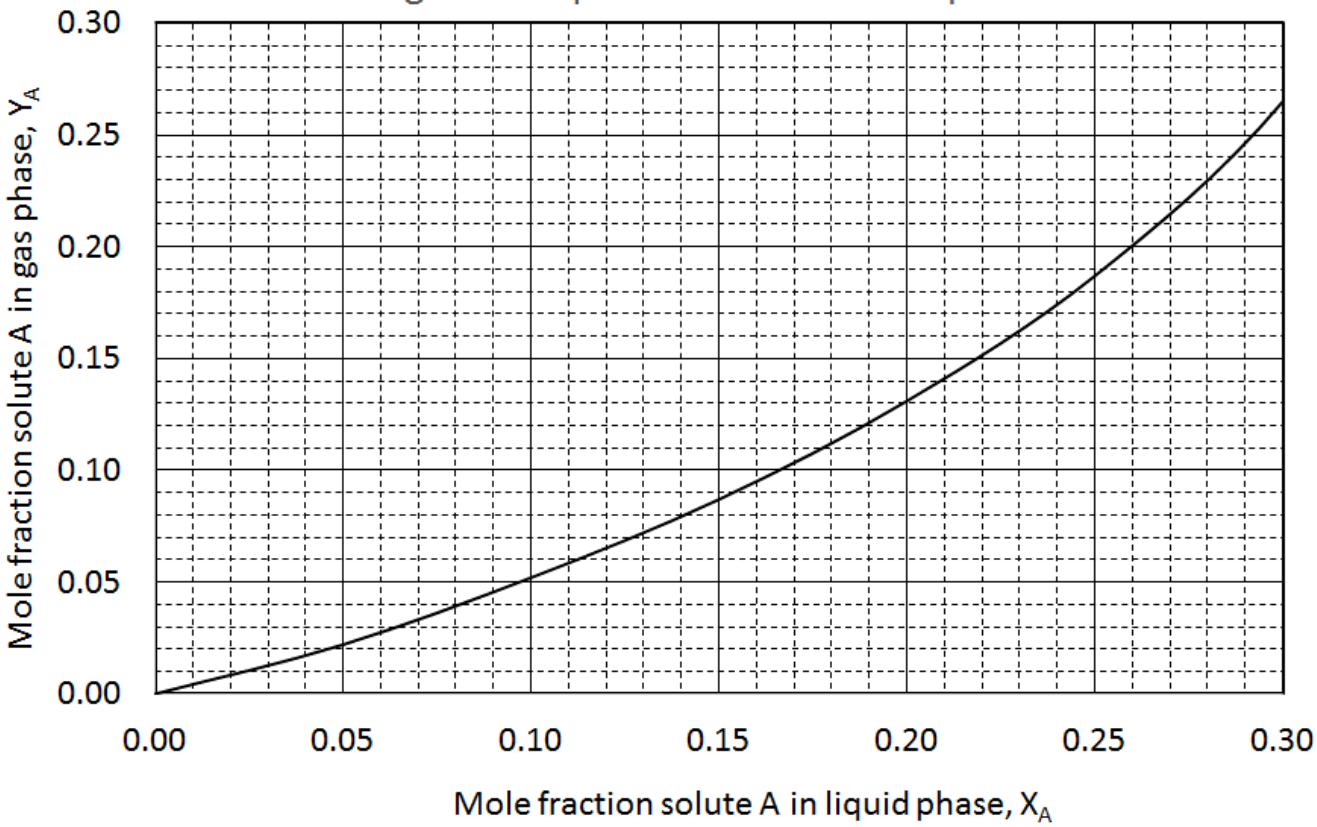


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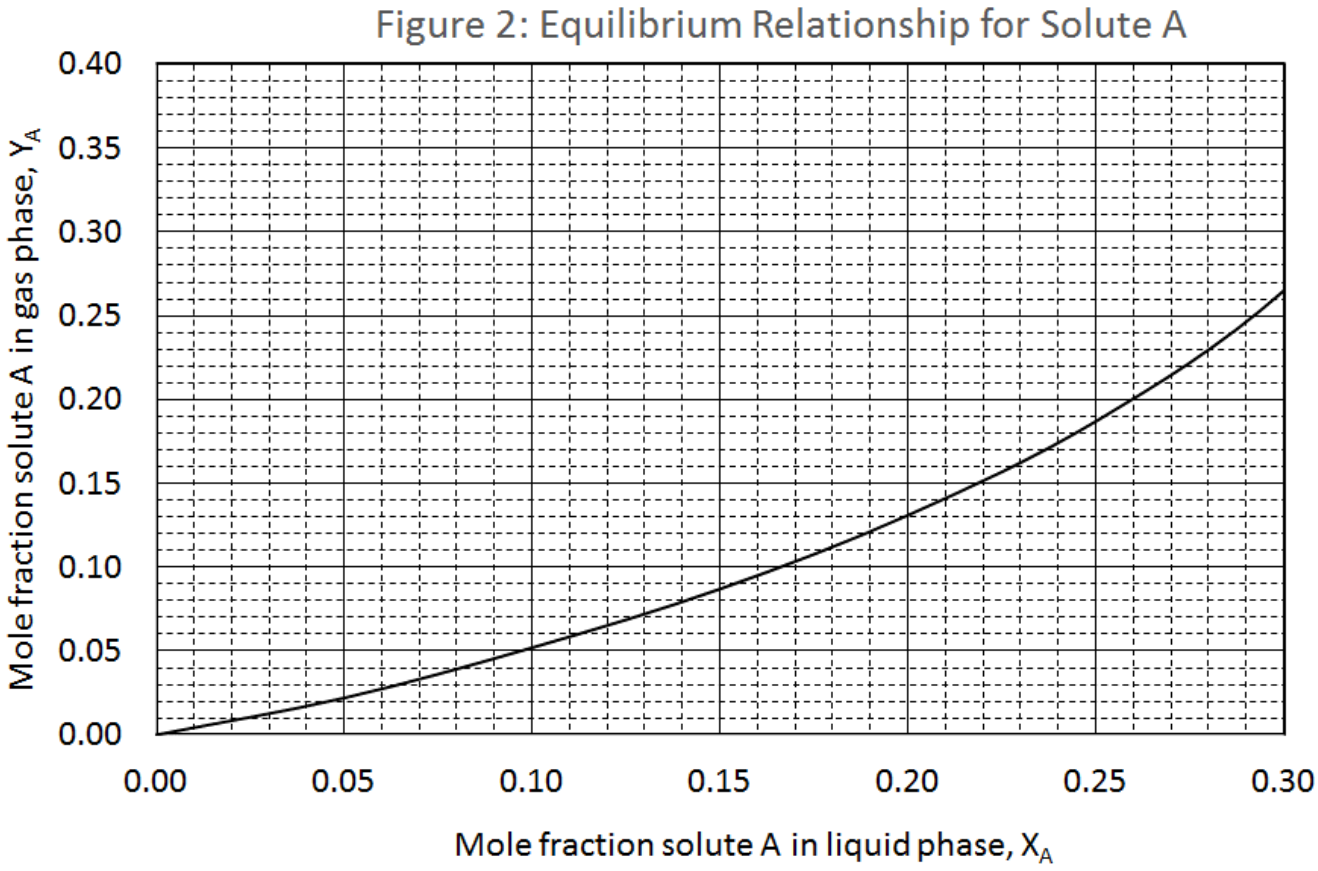
|---|---|
| | |

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