National Exams December 2009

04-Chem-A3 Mass Transfer Operations

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. Any non-communicating calculator is permitted. This is an OPEN BOOK exam.
   Note: You must indicate the type of calculator being used; i.e., write the name and model designation of the calculator on the first inside left-hand sheet of the exam work book.

3. Any three (3) questions (out of 4) constitute a complete paper. Only the first three questions as they appear in your answer book will be marked.

4. There are 4 written pages and 2 attachments.

Please do not put any questions on the covering page; *i.e.*, start exam questions on page 2

Question 1: (33 marks)

As one method of reducing the chlorine consumption in a water-treatment plant, it has been proposed to pass the water over particles of solid iodine. You are to calculate, using the data in the table below, the rate of I_2 (mg/h) dissolution into the water from a single particle.

ITEM	VALUE	UNITS
Particle diameter	2	mm
Diffusion coefficient of I_2 into water	1.3×10^{-9}	m^2/s
Water velocity	1.75	m/s
Solubility of I_2 in water	0.243	g/L

You may use 1 cP and 1000 kg/m^3 as the viscosity and density of water.

Question 2: (33 marks)

A distillation to separate a process stream containing 40 mole% chloroform ($CHCl_3$) and 60 mole% toluene is in operation. The distillate contains 92% $CHCl_3$ and the bottoms 2% $CHCl_3$. Data are as follows:

Feed composition	X_F	0.40	mole fraction of 1
Feed quality		saturated liquid	
Distillate composition	X_D	0.92	mole fraction of $CHCl_3$
Bottoms composition	X_B	0.02	mole fraction of $CHCl_3$
Reflux ratio	R_D	2.0	
Heat of vaporization of $CHCl_3$	λ_1	32,400	kJ/kmol
Heat of vaporization of C_7H_8	λ_2	37,600	kJ/kmol

CASE I: calculate:

a) The theoretical number of stages, using the attached X-Y plot;
b) The flow rates of the top streams: D, L and V;
c) The flow rates of the bottom streams: B, $\overline{L}$ and $\overline{V}$;
d) The equations for the the top (rectifying) and bottom (stripping) operating lines;
e) The heat added to the reboiler at the bottom;
f) The heat removed in the condenser at the top.

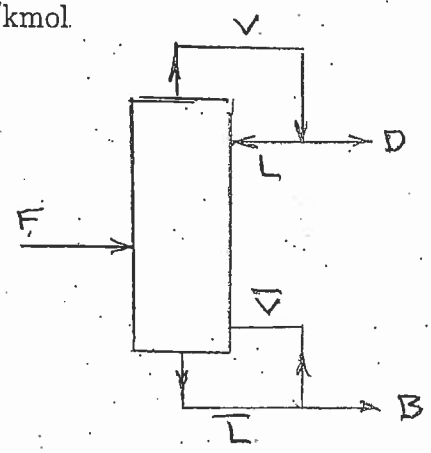


Figure 2-a: Distillation of 1 and 2

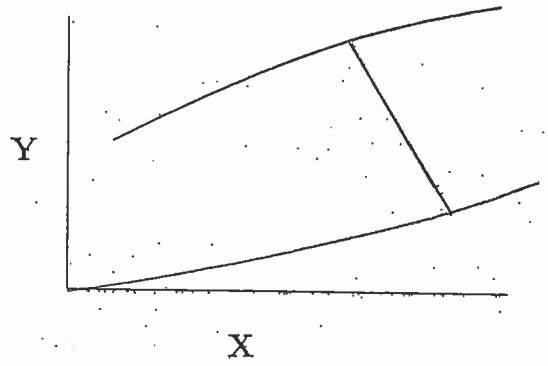
Case II:

As part of a proposed plant up-grade, the feed stream will now be available as 85% vapour with the same composition. Assuming that the distillate composition number of stages and reflux ratio are to remain the same, discuss the difference in operation of the with regard to the bottoms composition and heat effects in the condenser and reboiler.

Figure 2-b, the equilibrium X-Y plot, is attached.

Question 3: (33 marks)

An analysis of a gas absorption operation has resulted in the familiar X-Y plot shown below:



In order to help the absorption mass transfer, you will be trying the following, and giving an explanation of what happens:

a) A chemical is dissolved in the liquid which results in a greater solubility of the gas in the liquid. What will happen to the equilibrium curve? (Sketching the "before" and "after" curve would probably help in the explanation.)

b) It is noted that when the chemical is introduced, the resistance to mass transfer *in the liquid phase* is decreased (ie the mass transfer coefficient is increased). Explain what happens to the Δ-line at a given gas concentration. Again, it is probably easiest to sketch the two cases, before and after.

c) What would happen to the operating line if the liquid rate were increased?

Question 4: (33 marks)

The system to be considered is acetic acid (HAC); methyl acrylate (MA); and benzoyl alcohol (BA). Tie-line equilibrium data are given in the table below:

Methyl Acrylate Layer			Benzoyl Alcohol Layer		
MA	HAC	BA	BA	HAC	MA
86.7	8.0	5.3	90.0	7.0	3.0
77.5	16.5	6.0	82.0	14.2	3.8
66.0	26.0	8.0	74.0	21.0	5.0
54.5	35.0	10.5	65.5	28.0	6.5
39.0	43.0	18.0	56.5	35.0	8.5
22.5	47.0	30.5	47.0	42.0	11.0

a) A mixture containing 52 kg of **HAC**, 130.9 kg of **BA** and 76.9 kg of **MA** is shaken and allowed to separate into two phases. Calculate the composition of the two phases, and the quantities of each.

b) It is then desired to solublize the two phases into one single phase by adding **HAC** to the two-phase mixture until the two phases are mutually soluble, i.e. form only one single phase. Calculate the amount of **HAC** to be added, and the composition of the resulting solution.

A triangular diagram is attached for your use.

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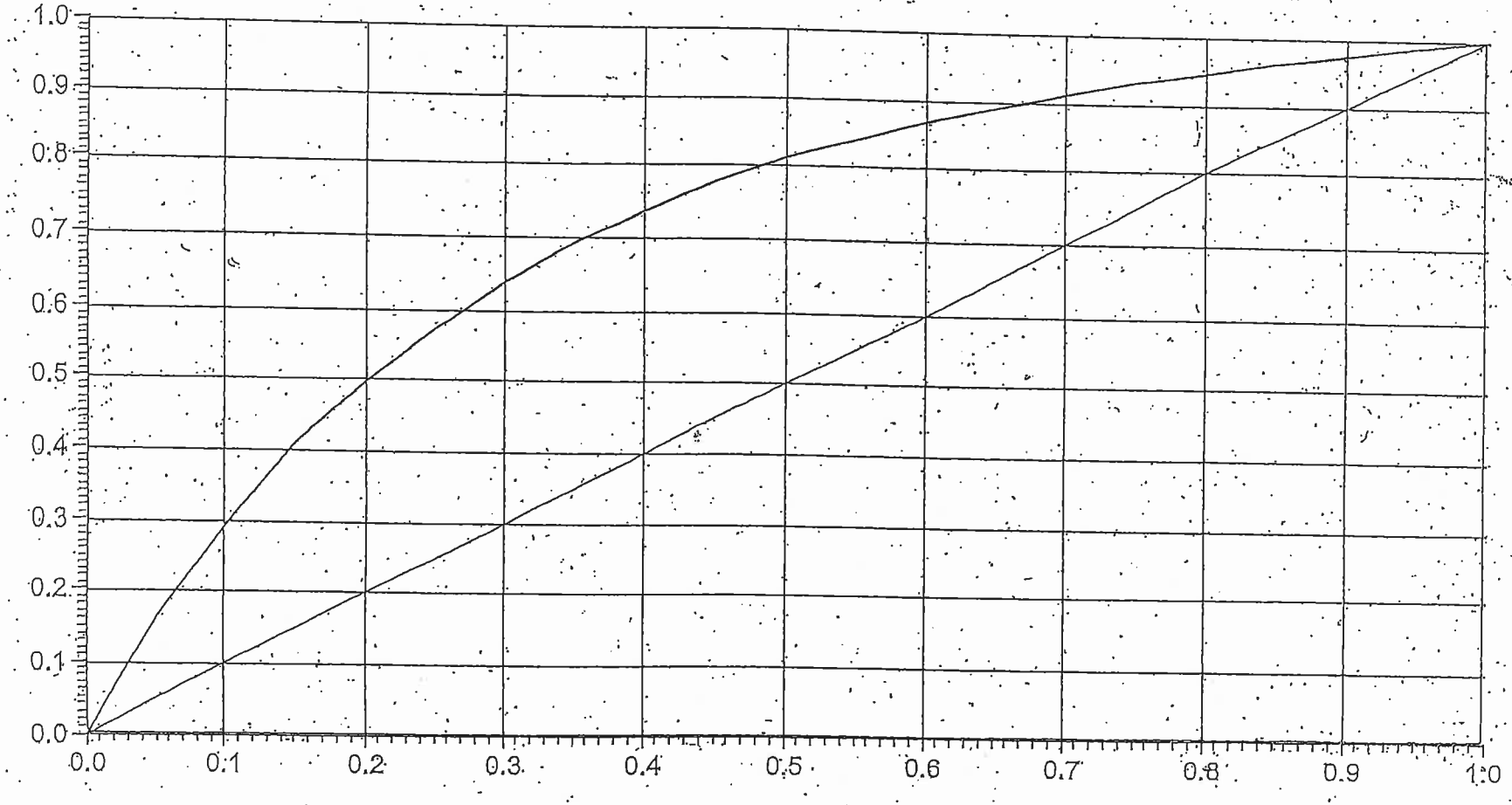
X-Y PLOT OF CHLOROFORM-TOLUENE



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QUESTION 4: TRIANGULAR DIAGRAM