National Exams May 2011

04-Chem-A3 Mass Transfer Operations

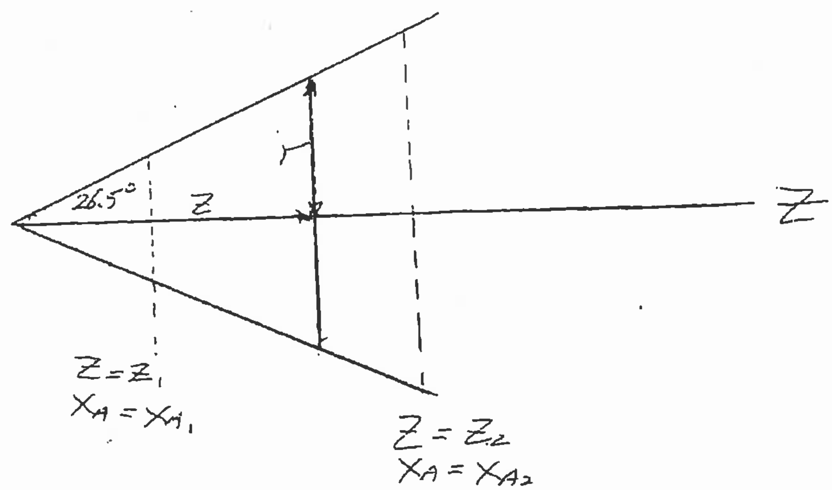
3 hours duration

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

Component A is diffusing from a point source inside a conical device as shown below. The sides of the cone are at a 26.6 degree angle so that the radius of the cone at any distance Z from the origin is equal to 0.5 Z. Derive an expression for the mole rate (kmol/s) of component A in terms of Z and X_A using the boundary conditions that at $Z = Z_1$, $X_A = X_{A_1}$ and at $Z = Z_2$, $X_A = X_{A_2}$. You may assume that $N_B = 0$.



Question 2: (33 marks)

In your plant, there is a stream of a mixture of 35 mol% benzene, 65% cycloheptane and has a vapour fraction of 0.25. at a flow rate of 100 kg-mol/h. You have recently de-commissioned a distillation column containing 8 theoretically-equivalent trays. You wish to separate the stream into a benzene-rich stream at the top containing 97 mol% benzene, and a bottom stream of 8 mol% benzene using this column (shown diagrammatically in Figure 2-a below). Calculate the following:

a) the reflux ratio required for the separation;
b) the flow rates of the top streams, D, L, V;
c) the flow rates of the bottom streams B, $\overline{\text{L}}$ and $\overline{\text{V}}$.

Two copies of Figure 2-b, the equilibrium X-Y plot are attached.

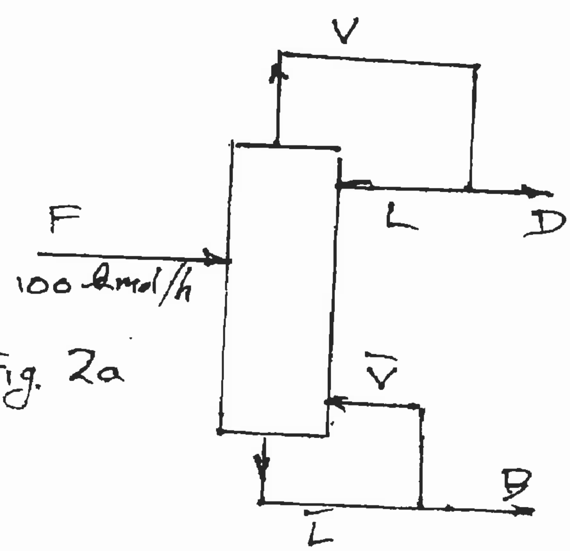


Fig. 2a

A wetted-wall column 2 m high and 25 m diameter is being used to add a small amount of a chemical A to an air stream flowing at 50 kmol/h in an apparatus shown schematically below. The mole fraction of the chemical in the exit stream is 0.020 and the entering air is free of chemical A. The total pressure is 1 atmosphere and the vapour pressure of the liquid is 75 mmHg.

It has been suggested that by increasing the height of the column to 4 m, the mole fraction of component A in the exit gas could be increased. You are to calculate the mole fraction of A in this case.

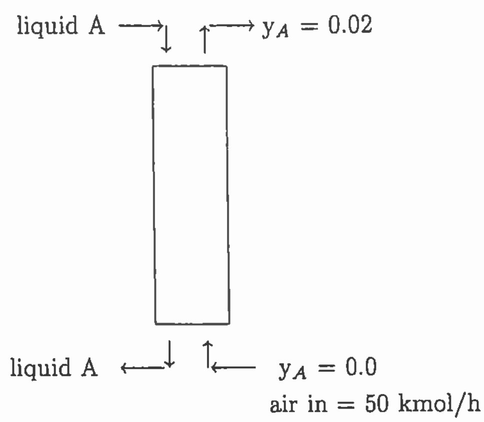


Figure 3: **Wetted-Wall Column—Question 3**

Question 4: (33 marks)

Part A:

A liquid-liquid extraction column is being used to remove Ethylbenzene (EB) from a Hexane (H)-rich solution by counter-current extraction with pure tri-Ethylene Glycol (TEG). As indicated in Figure 1 below, the feed to the column is 100 kg/h of a solution containing 36% (weight) EB, 62% H and 2% TEG. It has been determined that the top outlet stream (V_A) has a flow rate equal to that of the bottom stream (L_B). Under these conditions, calculate the flow rate and composition of the two outlet streams, and the flow rate of the pure TEG to the column. The equilibrium triangular diagram required is attached.

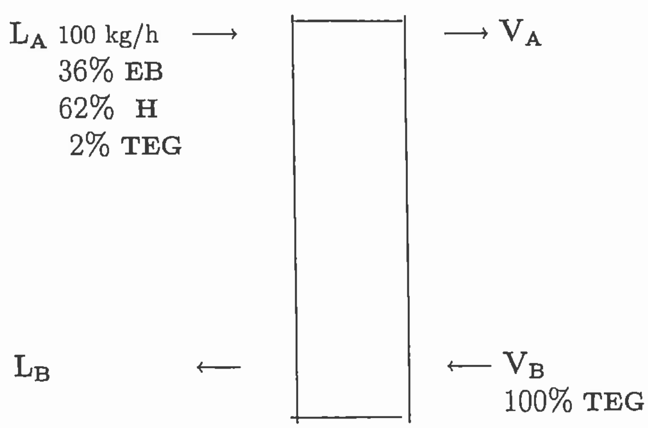


Figure 4: **Liquid-Liquid Extraction Column, Question 4**

Part B:

You have 100 kg of a solution containing 40% EB, 10% H and 50% TEG.

i. Calculate the compositions and amounts of the two phases in the above mixture.

ii. Calculate how much Hexane and EB would have to be added to the mixture to convert it into one phase.

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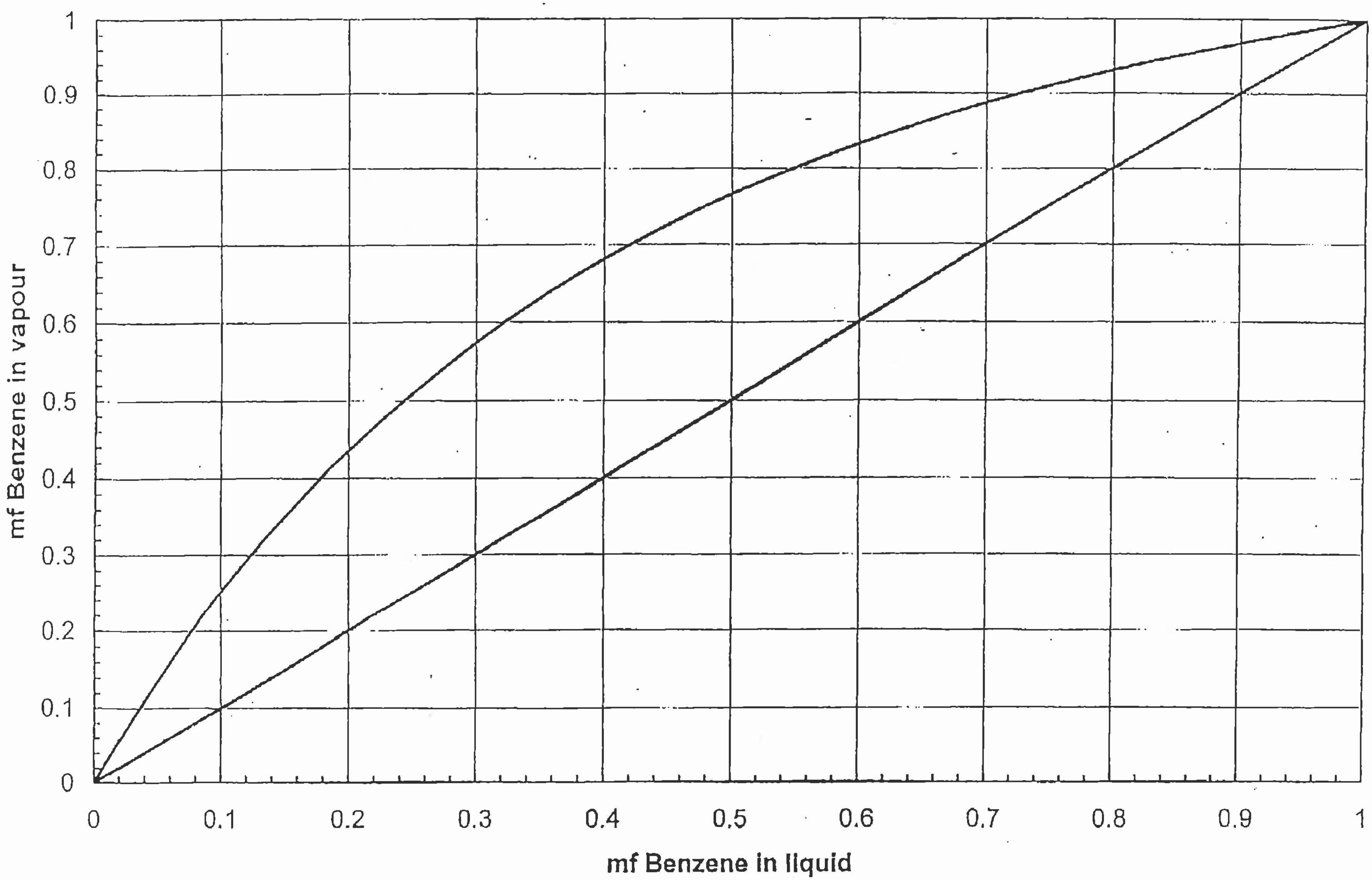
Question 2: System Benzene-Cycloheptane



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QUESTION 4

SYSTEM: EB
H
TEG