National Exams Dec 2010

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 3 attachments.

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

Marking Scheme

1. (a) 23 marks; (b) 10 marks
2. (a) 5 marks; (b) 10 marks; (c) 8 marks (d) 10 marks
3. (a) 20 marks; (b) 13 marks
4. (a) 20 marks; (b) 13 marks

A new asthma drug delivery device has been invented shown schematically below. It consists of two tubes connected at a right angle. The bottom tube is 4 cm in diameter and 15 cm long; the top tube is 2 cm in diameter. Air is blown into the end of the tube at a velocity V; the bottom tube is filled with the drug to a height of 5 cm. For theraputic effect, the mole fraction of the drug at the end of the tube is to be 0.005. You are to calculate:

a) the rate of evaporation of the drug in mg/min;

b) the velocity of air (m/min) required to achieve 0.005 mole fraction at the end.

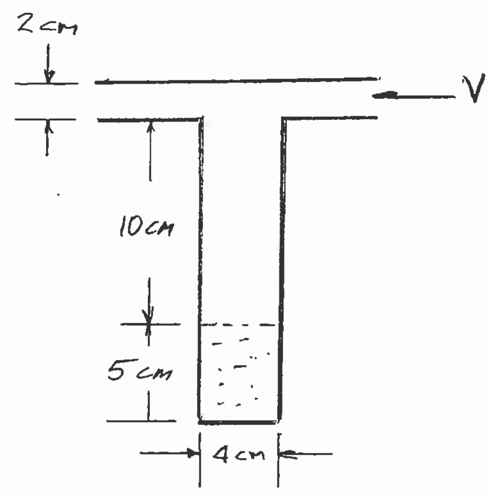


Table 1: **Data Required for Question 1**

ITEM	VALUE	UNITS
Pressure	101.3	kPa
Temperature	20	°C
Vapour pressure of drug @ 20 °C	150	mmHg
Diffusion coefficient	4.3×10^{-6}	m^2/s
Molecular weight of drug	494	kg/kmol

Question 2: (33 marks)

The feed to a distillation column (shown schematically as Fig. 2-a below) has a concentration of 45 mol% benzene, 55% cycloheptane and enters as a saturated liquid (at its boiling point) at a flow rate of 100 kg-mol/h. You are to design a column (shown diagrammatically in Figure 2-a below) to separate this feed into one containing 98% benzene; the other to have 2% benzene. The column is to have a reflux ratio of 3.0.

You have been asked to evaluate two specific cases as to the effect on the operation of the distillation column:

CASE I: Feed enters as a saturated liquid (at its boiling point);
CASE II: Feed enters as a saturated vapour (at its condensing point);

a) Calculate the number of theoretical stages for CASE I

b) Calculate the flow rates of the top streams, D, L, V and B, $\overline{L}$ and $\overline{V}$ for CASE I.

c) Calculate the bottoms composition (X_B) for CASE II if the top composition and the number of stages are to remain the same.

d) Calculate the flow rates of the top streams, D, L, V and B, $\overline{L}$ and $\overline{V}$ for CASE II.

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

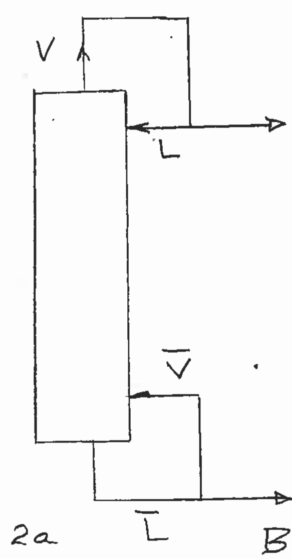
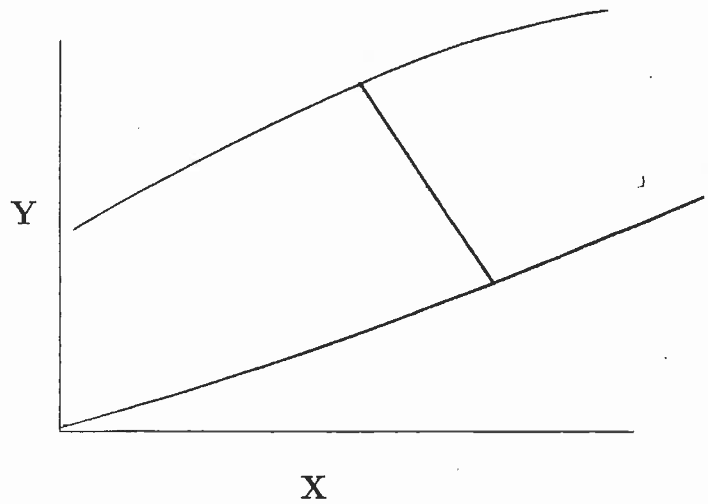


FIG 2a

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



a) The temperature of the column is to be increased. This will result in a net increase in the individual mass transfer coefficient on the gas side, but the liquid side coefficient is essentially unchanged. Also, the solubility of the gas in the liquid will decrease. Show qualitatively what happens to the above plot when this occurs.

b) What would happen to the operating line if the liquid rate were decreased?

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 29% (weight) EB, 69% H and 2% TEG. It has been determined that the top outlet stream (V_A) has a flow rate 3 times 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.

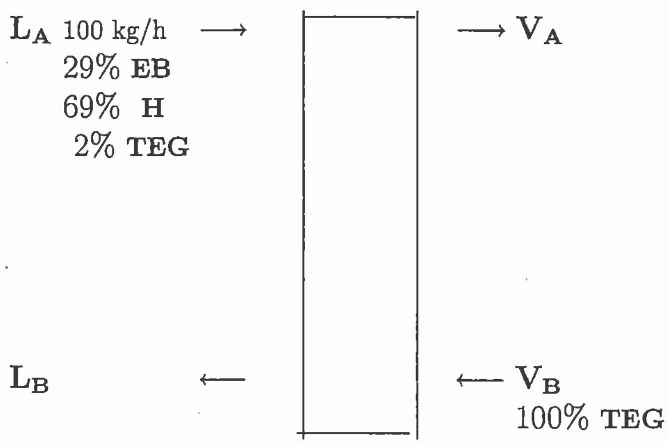
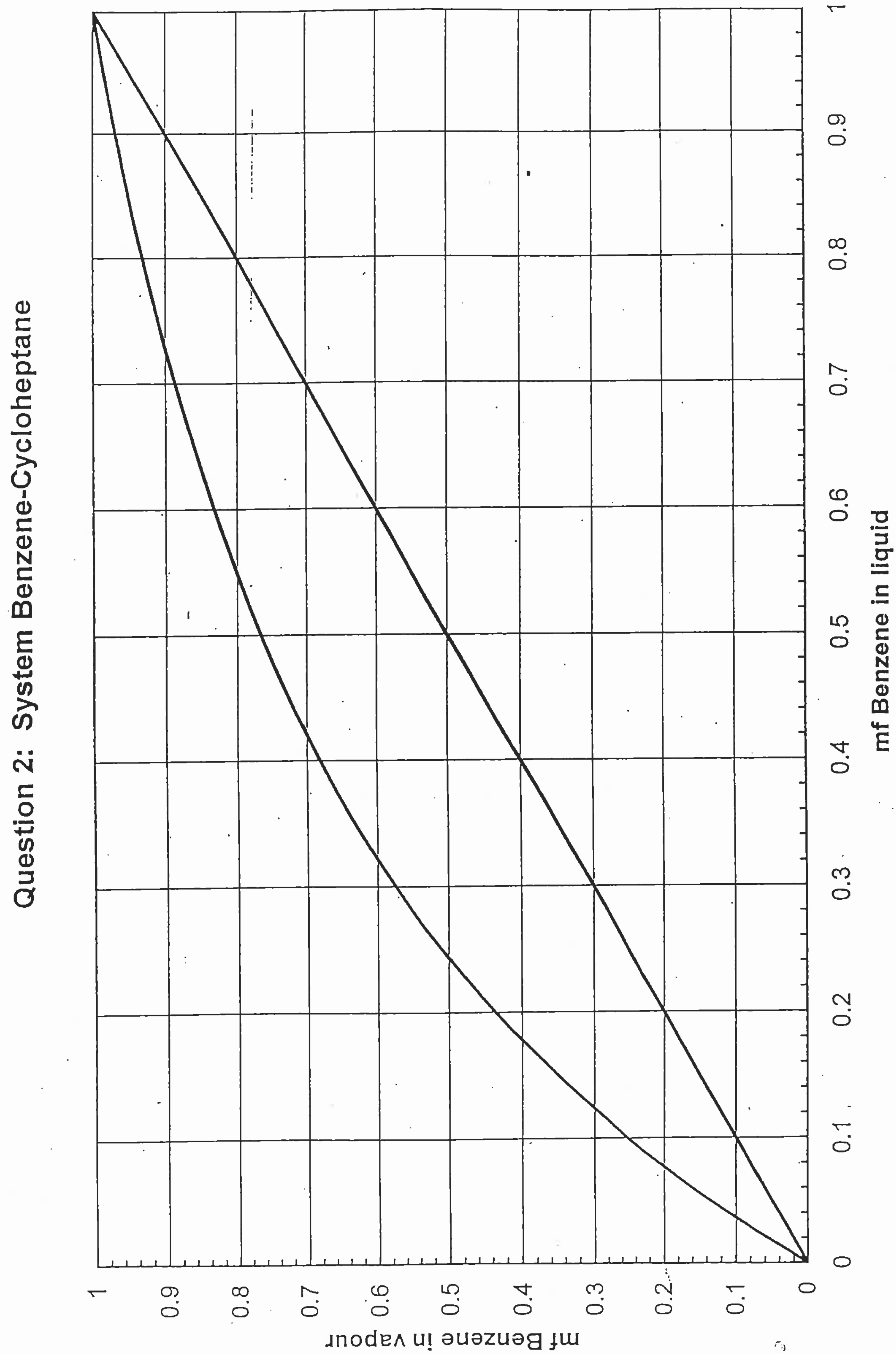


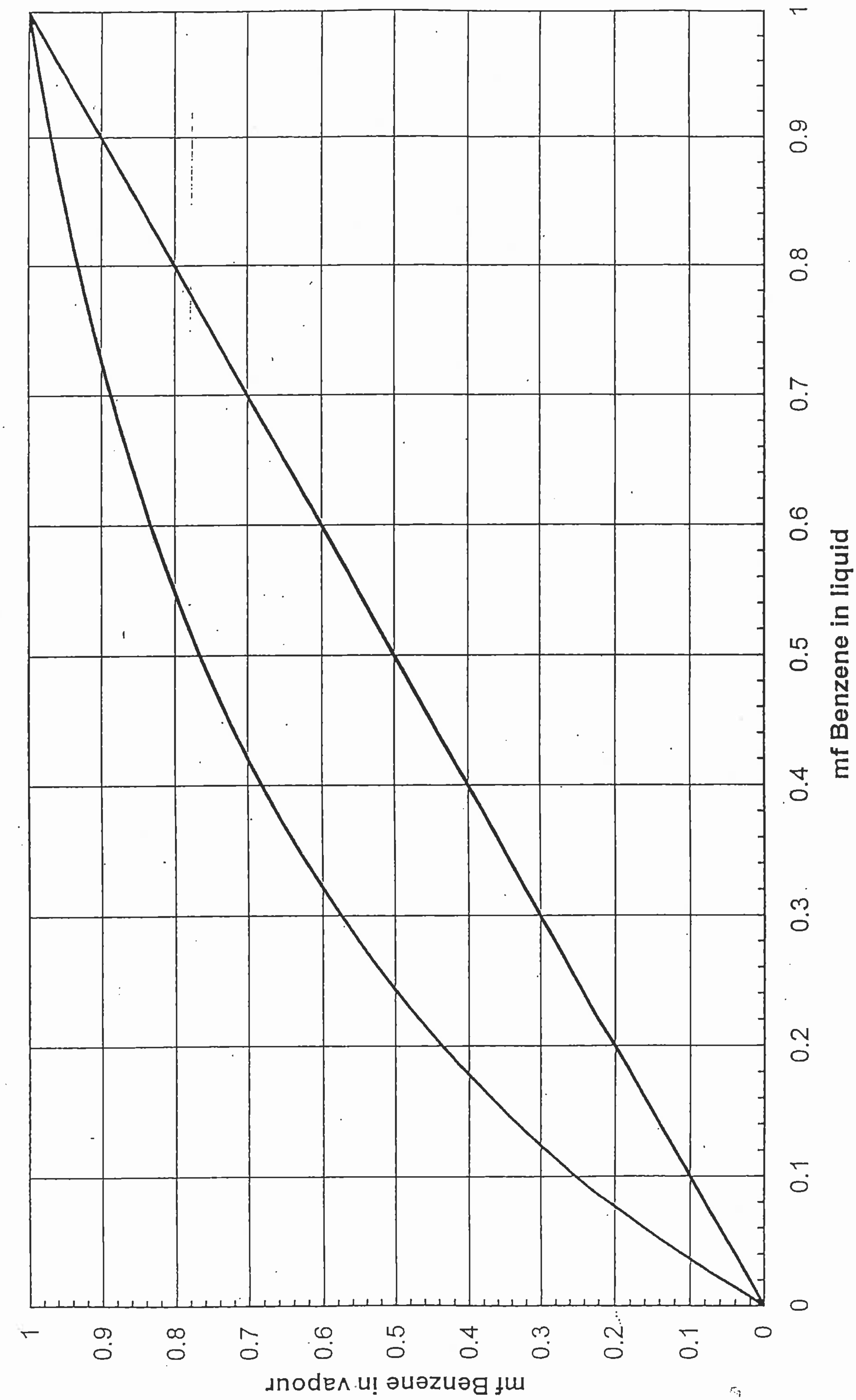
Figure 4: **Liquid-Liquid Extraction Column, Question 4**

Part B:

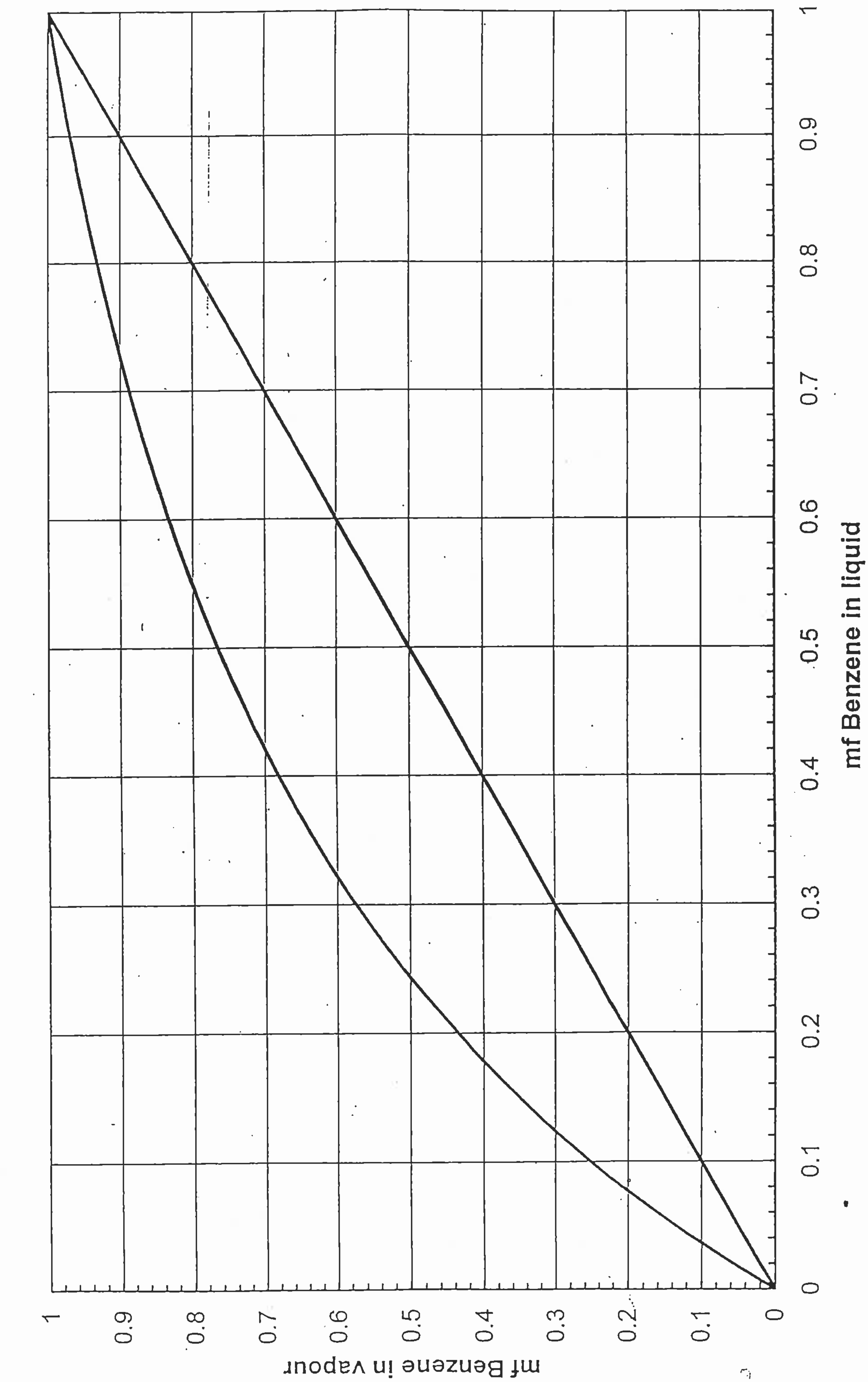
You have 100 g of a solution containing 75% EB, 5% H and 20% TEG. Calculate how much H would have to be added to the solution just before it starts to separate into two phases. Calculate the composition of the resulting solution.

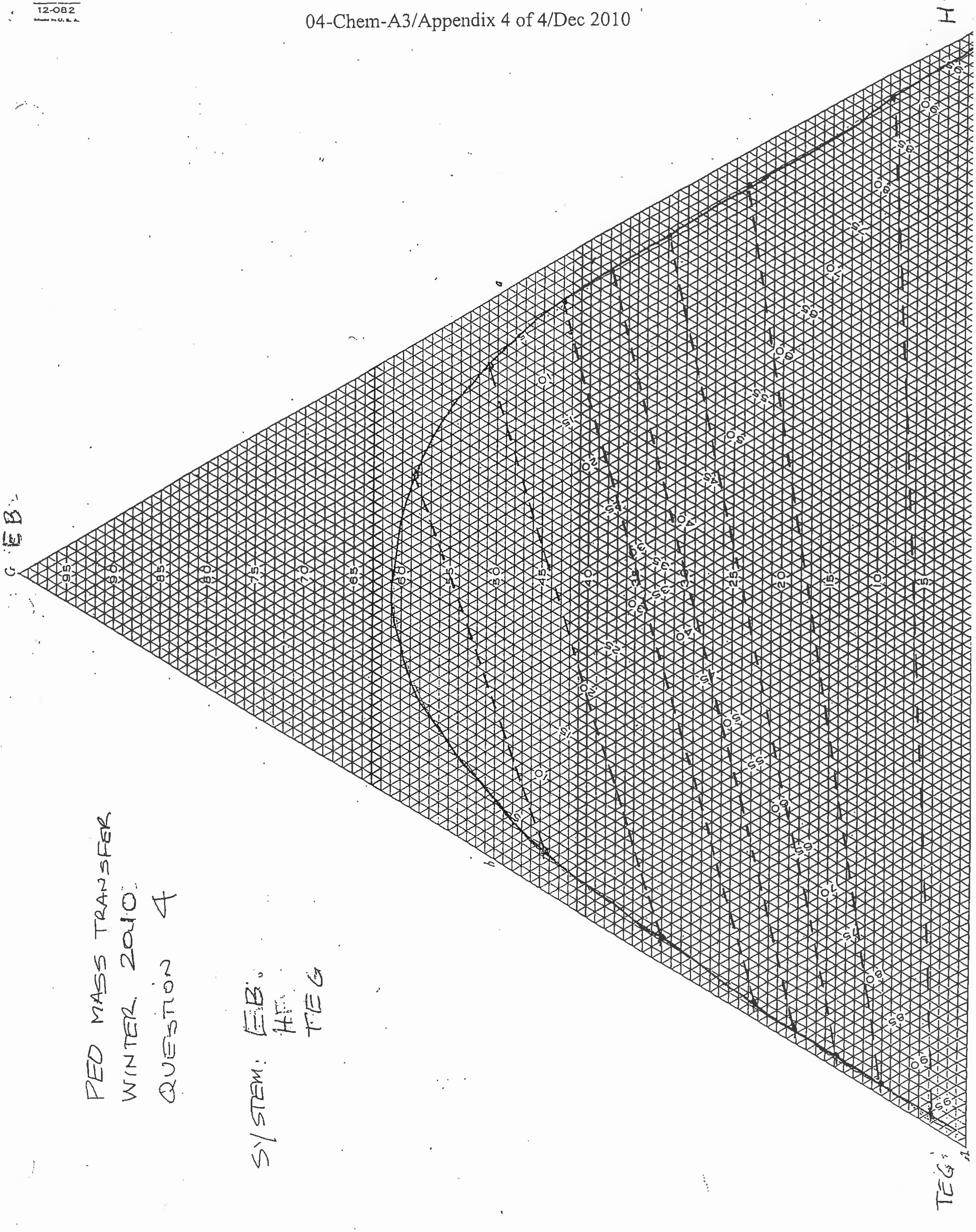

Question 2: System Benzene-Cycloheptane
mf Benzene in liquid
mf Benzene in vapour
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Question 2: System Benzene-Cycloheptane



Question 2: System Benzene-Cycloheptane





PED MASS TRANSFER
WINTER 2010
QUESTION 4

SYSTEM: EB
H
TEG