National Exams May 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 2 attachments.

Question 1: (33 marks)

An experiment to measure the diffusion coefficient of a solid organic compound $C_{10}H_{16}O$ consists of suspending a sphere of the substance in a flowing stream of air and measuring the weight loss as a function of time. The following data have been obtained:

ITEM	VALUE	UNITS
Particle diameter (initial)	20	mm
Air velocity	6.3	m/s
Air temperature	70	°C
Air pressure	101.3	kPa
Vapour pressure of $C_{10}H_{16}O$ @ 70 °C	2.5	mmHg
Rate of weight loss (initial)	0.158	g/min

Calculate the diffusion coefficient of the compound in air.

Question 2: (33 marks)

It is necessary to separate by distillation 100 kmol/h of a process stream containing 60 mol% benzene and 40 mol% ethylbenzene, with the objective of obtaining a high purity (99.5 mol%) benzene product and an ethylbenzene product. Two schemes are to be considered:

Scheme I: An initial flash separation prior to distillation, and then distil the resulting benzene-rich product to remove the ethylbenzene. This process is shown schematically in the figure below. The feed to the flash separator is at its boiling point, with 60% vapour. The vapour stream is then fed to a distillation column having a reflux ratio of 1.

Scheme II: A direct distillation of the process stream (at its boiling point); reflux ratio of 1.

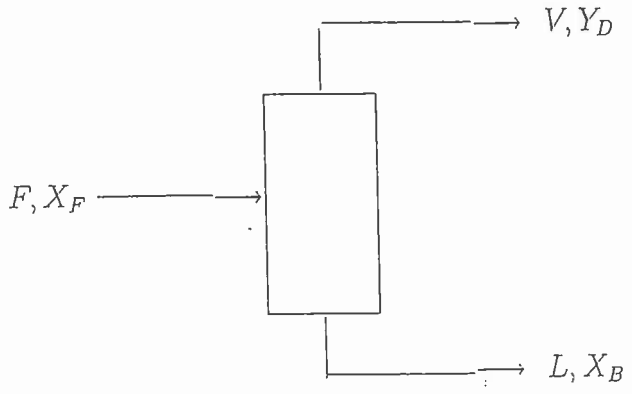
You are to determine:

a) the concentration of the vapour and liquid streams from the flash operation;

b) the number of stages necessary to produce a bottoms product of 99% ethylbenzene for scheme I.

c) the number of stages for the distillation column of scheme II to produce the two products of the same composition as in scheme I.

Equilibrium X-Y plots are included for your use.



Question 3: (33 marks)

A absorption column is set up for the purpose of removing cyanogen (CN) from a gas by contact with water. The following data are available:

$k_y a$	312 kmol/m^3· h
$k_x a$	1800 kmol/m^3· h
Pressure	1 atm
Equilibrium	$Y^* = 5.3\ (X^*)^{1.07}$
CN in inlet air	1.25% by volume
CN in outlet air	75 ppm by volume
CN in inlet liquid	0.0
Inlet liquid flow rate	350 kmol/m^2· h
Inlet gas flow rate	85 kmol/m^2· h

a) Calculate the number of transfer units N_{tOG} and N_{tOL}.

b) Calculate the height of transfer units H_{tOG} and H_{tOL}.

c) Calculate the total height of the column to perform the absorption.

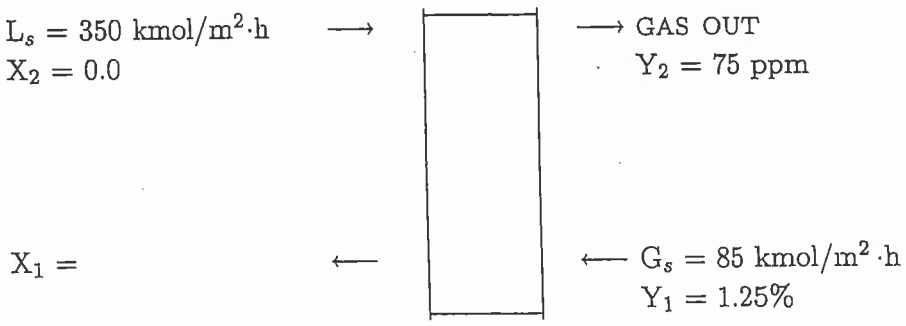


Figure 3: **Gas Desorption Column—Question 3**

A single-stage extraction unit, shown in Fig 4, is being use to extract HAc from CF using W as the extractant. The feed to the column is 100 kg/h and consists of 35% (weight basis) HAc and 65% CF. It is desired for the bottom stream (L_B) to have a concentration of 20% HAc. The extracting liquid is feed is pure W. Calculate:

a) The composition of the two exit streams, V_A and L_B;

b) The flow rates of the two exit streams and the inlet stream V_B

A triangular diagram with the equilibrium curve and associated tie-lines is attached for your use in this problem.

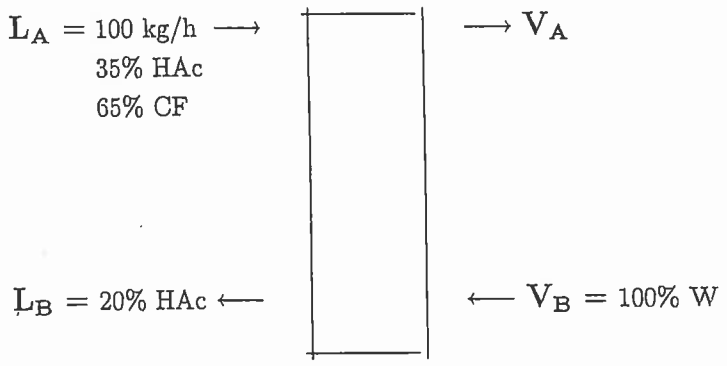
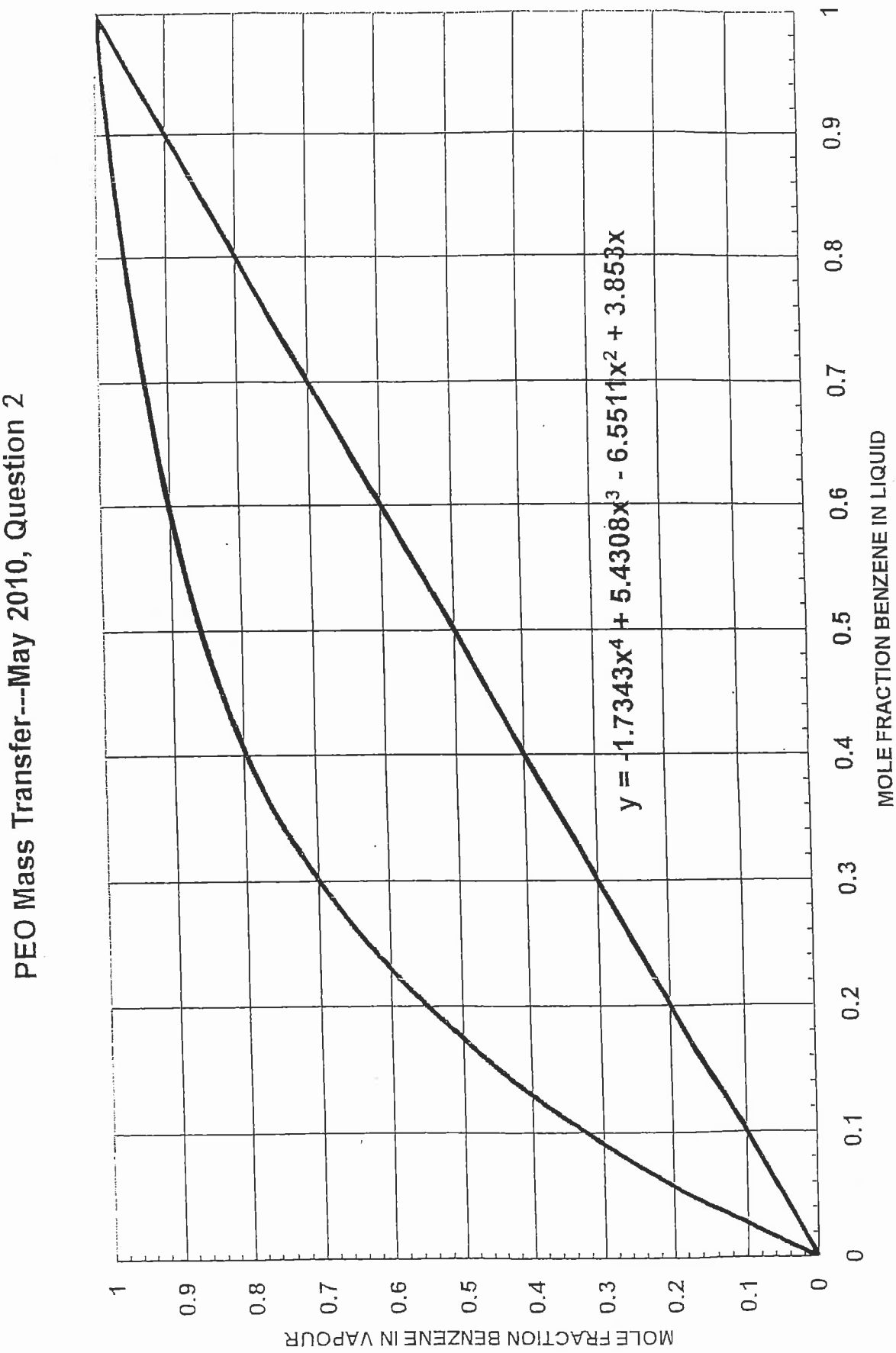
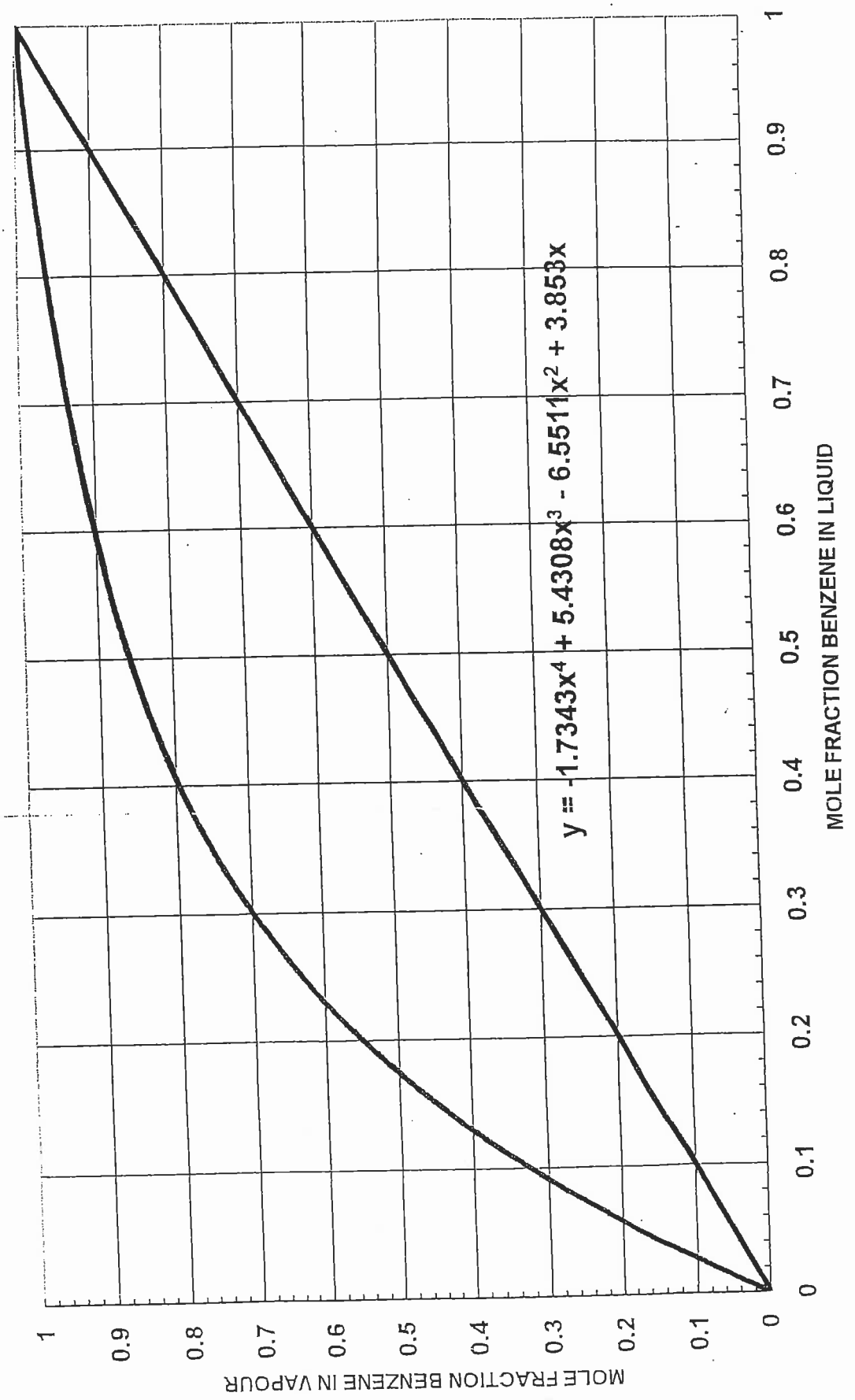


Figure 4: **Liquid-Liquid Extraction Column—Question 4**


PEO Mass Transfer---May 2010, Question 2
MOLE FRACTION BENZENE IN VAPOUR
MOLE FRACTION BENZENE IN LIQUID
y = -1.7343x4 + 5.4308x3 - 6.5511x2 + 3.853x
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1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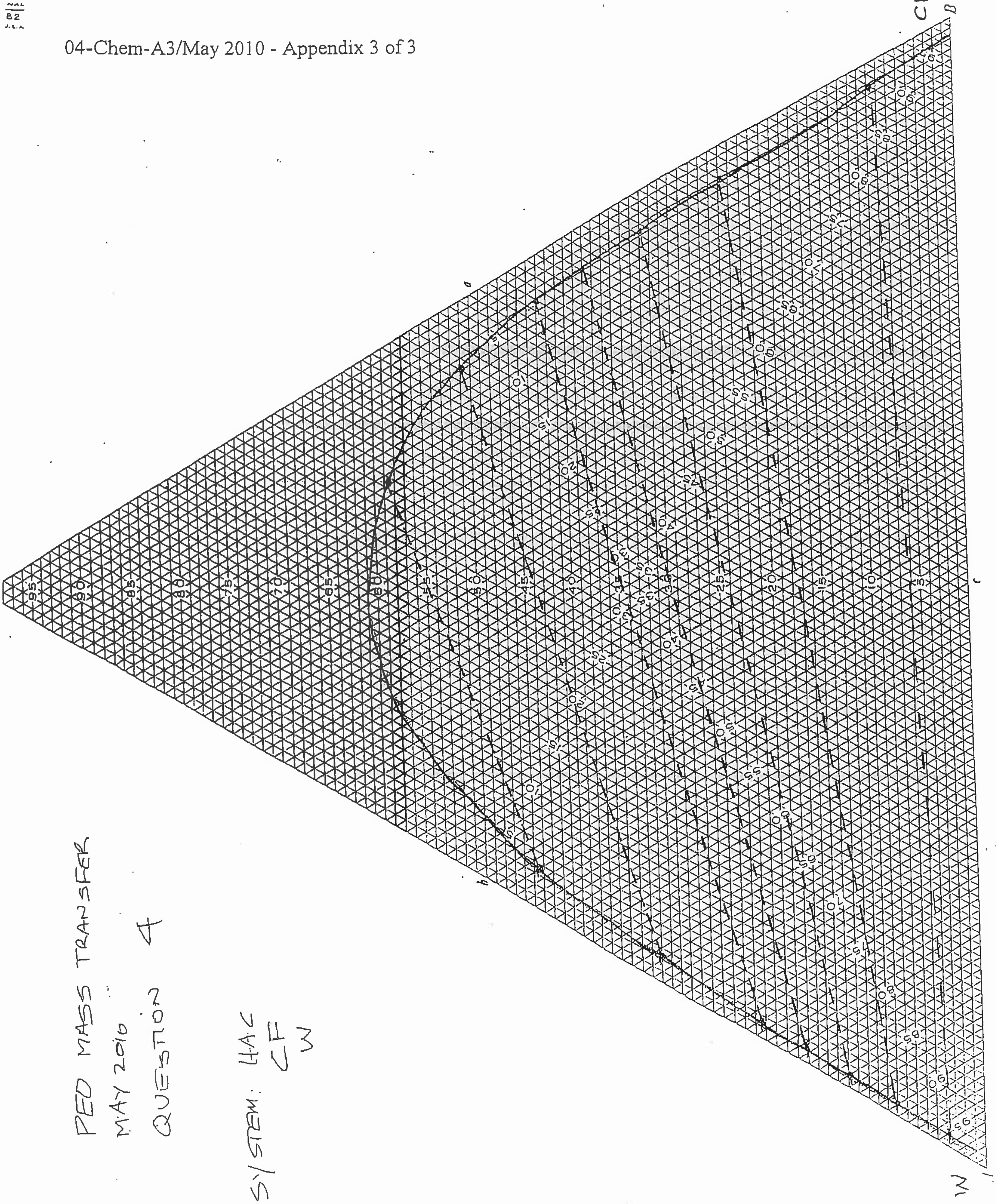
0.6
0.7
0.8
0.9
1



Triangular Co-ordinate