National Exams December 2008

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 3 written pages and 3 attachments.

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

Question 1: (33 marks)

You are doing an experiment which involves the evaporation of liquid diethyl ether ($C_4H_{10}O$) in a glass cylinder 0.5 m tall, 10 cm in diameter under a fume hood at 30°C, 1 atm absolute pressure.

(a) Calculate the rate of evaporation of diethyl ether (g/h) when the concentration at the outlet of the tube is 0.700 mole fraction.

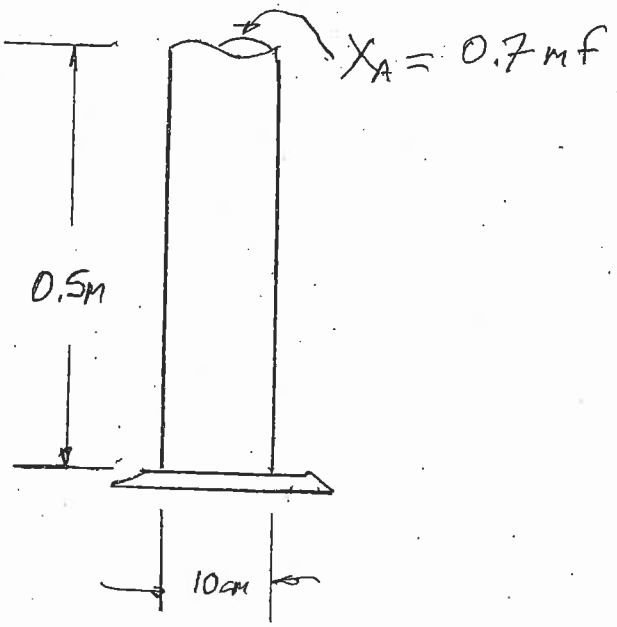
(b) It has been pointed out that the concentration of 0.7 mole fraction is too high for safe operation. It is intended to reduce this concentration by lowering the temperature of the entire experiment to 20°C and increasing the air flow in the hood. Calculate the resulting concentration, assuming that the rate of evaporation is to remain unchanged from Part (A).

Data Required:

Diffusion coefficient of $C_4H_{10}O$ in air: 0.0910 cm^2/s at 30°C

Vapour pressure of $C_4H_{10}O$:

$$P_v \text{ (mmHg)} = \exp\left(18.0 - \frac{3488}{T(\text{K})}\right)$$



Question 2: (33 marks)

The feed to a distillation column has a concentration of 55 mol% benzene, 45% 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 1% benzene.

The column is to have a reflux ratio of 1.5. The heats of vapourization of benzene and cylcoheptane are 393.3 and 350.3 kJ/kg respectively. Two copies of Figure 2-b, the equilibrium X-Y plot, are attached.

Calculate the following items:

a) flow rates of the top streams D, L and V
b) flow rates of the bottom streams B $\overline{L}$, and $\overline{V}$;
c) recovery of benzene in the overhead product;
d) recovery of cylcoheptane in the bottoms;
e) condenser heat effects at the top;
f) boiler heat effects at the bottom;
g) theoretical number of stages to do the separation.

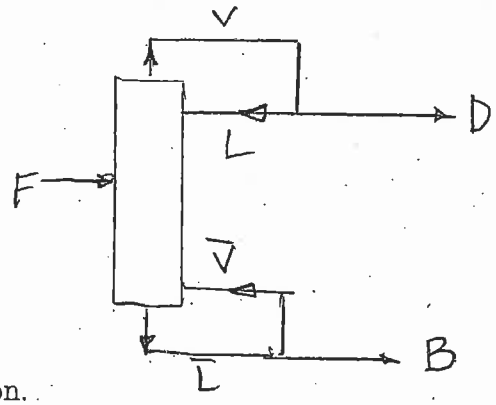


Figure 2-a: **Distillation of C_6H_6 and C_7H_{14}**

Question 3: (33 marks)

A 4-meter high packed tower is being used to remove H_2S from a gas stream at 101.3 kPa and 30°C. The inlet gas volumetric flow on a per unit area of column is 1200 $m^3/m^2 \cdot h$ and contains 5% (v/v) H_2S. It is desired to remove 98% of the H_2S from the gas and absorb it in water which is subsequently treated biologically. It has been found that the maximum concentration of H_2S which can be tolerated by the treatment system is 500 ppm (w/w). You are to calculate the following:

a) the flux of water required ($kg/m^2 \cdot h$;
b) the values of the overall mass transfer coefficients, K_Ya and K_Xa;
c) the height of the overall transfer units H_{Oy} and H_{Ox}.

The equilibrium relationship is: $Y^* = 81.4\,X^*$. You may use the lean gas approximation.

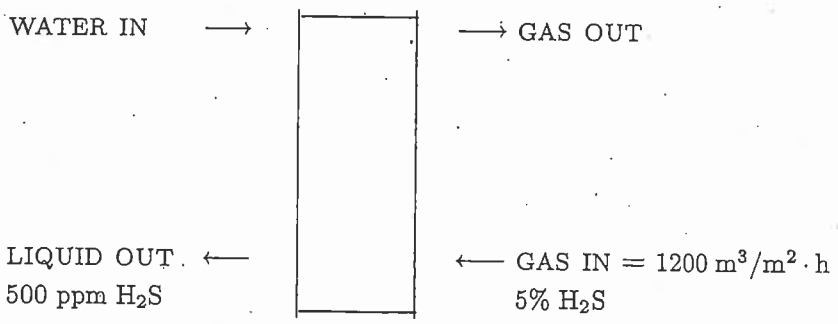


Figure 3: **Gas Absorption Column—Question 3**

Question 4: (33 Marks)

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.

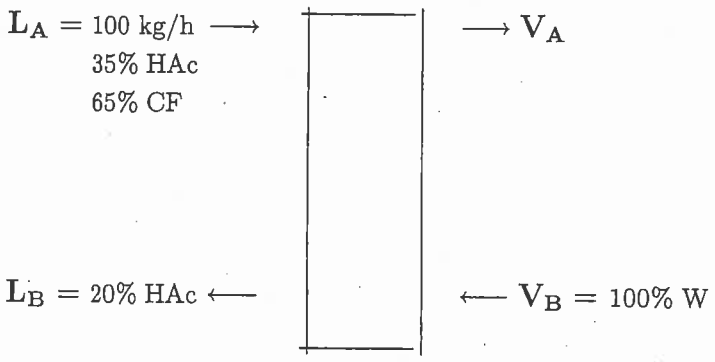
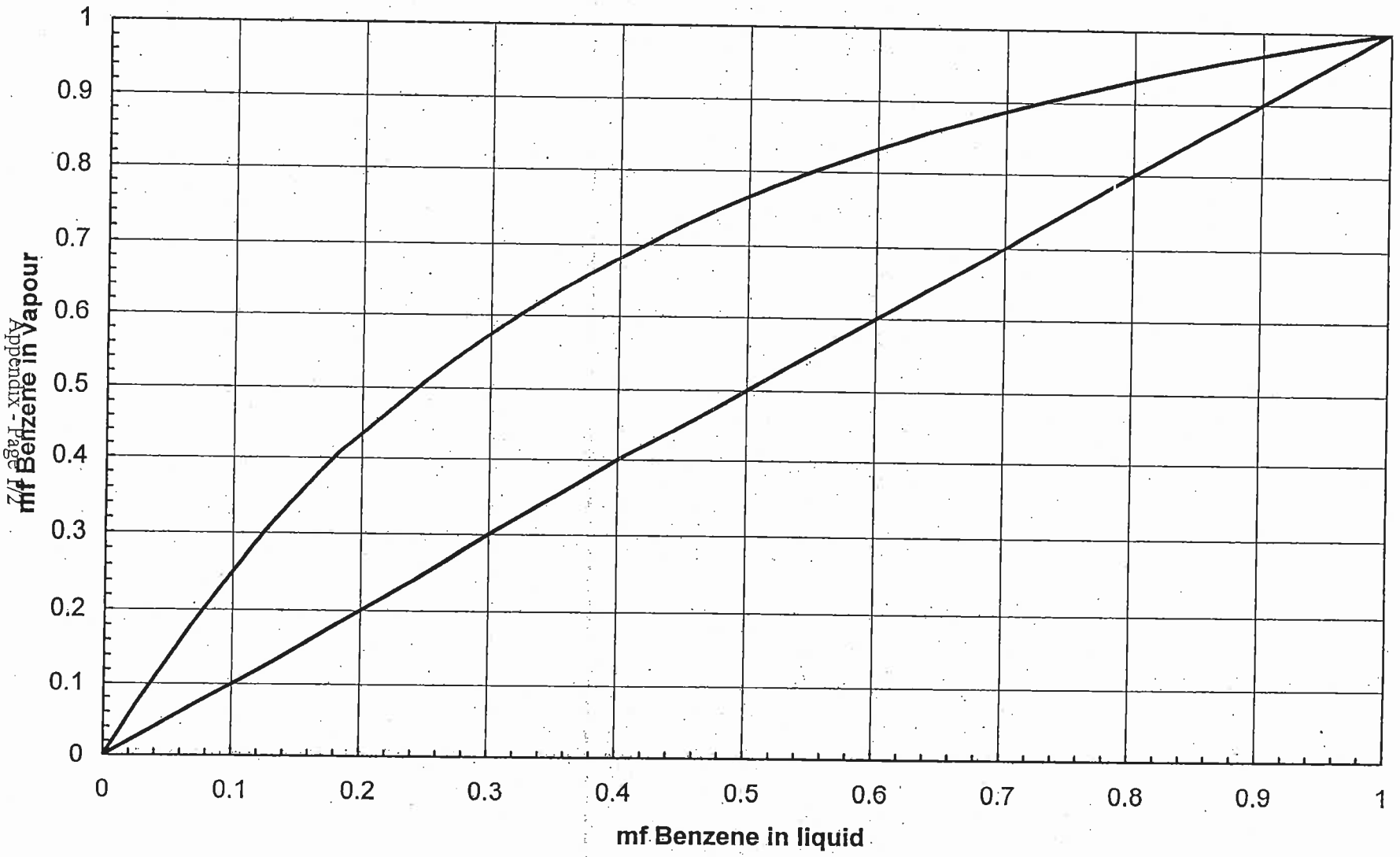


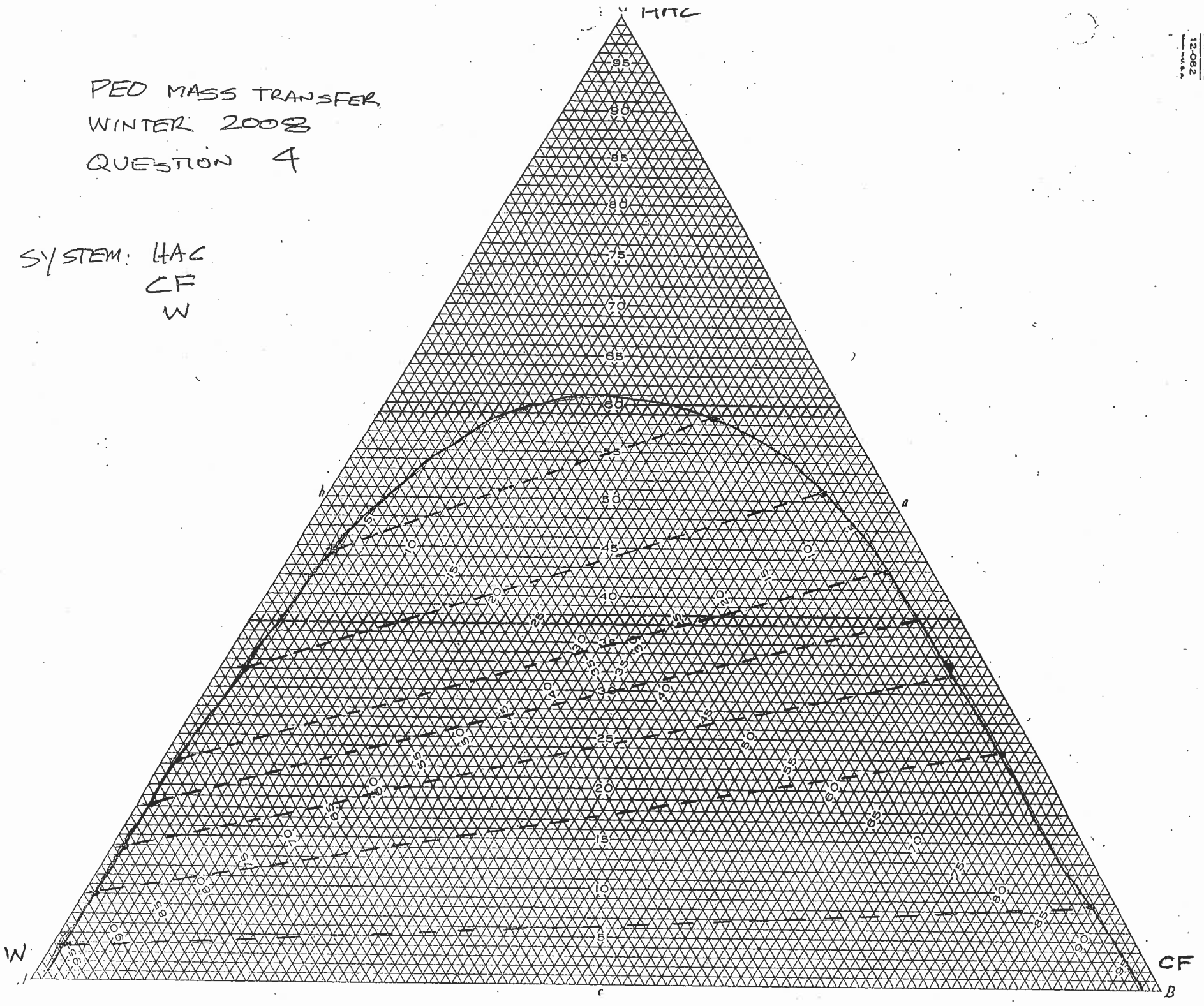
Figure 4: **Liquid-Liquid Extraction Column—Question 4**

Question 2: System Benzene-Cycloheptane



PEO MASS TRANSFER
WINTER 2008
QUESTION 4

SYSTEM: HAC
CF
W



Marking Scheme

1. 33 marks
   (a) 15 marks; (b) 18 marks;

2. 33 marks
   (a) 4 marks; (b) 4 marks; (c) 4 marks; (d) 4 marks; (e) 5 marks; (f) 5 marks; (g) 7 marks

3. 33 marks
   (a) 9 marks; (b) 12 marks; (c) 12 marks

4. 33 marks
   (a) 16 marks; (b) 17 marks;