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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	PROCESS TECHNOLOGY
COURSE CODE	:	BDJ 40203
PROGRAMMECODE	:	BDJ
EXAMINATION DATE	:	JULY / AUGUST 2023
DURATION	:	3 HOURS
INSTRUCTIONS	1.	ANSWER ALL QUESTIONS
	2.	THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.**
	3.	STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **FIFTEEN (15)** PAGES

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Q1 (a) Explain **TWO (2)** reasons why a tray column that is facing problems can be solved by replacing a section of trays with packings.

(4 marks)

(b) A rectification column is fed 400 kg mol/h of a mixture of 55 mol % benzene and 45 mol % toluene at 101.32 kPa abs pressure. The feed is saturated liquid at the boiling point. The distillate is to contain 95 mol % benzene and 5 mol % toluene and the bottoms containing 10 mol % benzene and 90 mol % toluene are to be obtained. The reflux ratio is 3:1. Data for the q-line is given in **Figure Q1 (b)**.

(i) Using the data given in **Table Q1 (b)(i)**, plot an equilibrium line and a 45° line on the x-y graph for benzene on the graph paper.

(3 marks)

(ii) Calculate the kg moles per hour distillate (D) and bottom (W).

(6 marks)

(iii) Determine the number of theoretical trays needed using the McCabe –Thiele method. Plot your answer using x-y graph in **Q1(b)(i)**.

(10 marks)

(iv) Identify the feed tray number.

(2 marks)

Q2 An evaporator is used to concentrate 5000 kg/h of a 20% solution of NaOH in water entering at 60 °C to a product of 50% solids, as shown in **Figure Q2**. The pressure of the saturated steam used is 169.06 kPa and the pressure in the vapor space of the evaporator is 12.35 kPa. The overall heat-transfer coefficient (U) is 1560 W/m^2.K. The steam table is shown in **Table Q2**.

(a) Calculate the kg per hour concentrated liquid (L) and vapor (V).

(4 marks)

(b) Determine the boiling point T_1 of the 50% concentrated solution by using **Figure Q2 (b)**.

(3 marks)

(c) Calculate the boiling point rise (BPR) value.

(2 marks)

(d) Determine the enthalpy of h_f and h_L, respectively, by using **Figure Q2 (d)**.

(4 marks)

(e) Calculate the amount of Hv.

(3 marks)

(f) Calculate the steam (S) used during the process.

(5 marks)

(g) Determine the heating surface area required in m^2.

(4 marks)

Q3 (a) Briefly explain about the liquid-liquid extraction process.

(2 marks)

(b) A single-stage extraction is performed in which 1250 kg of a solution containing 40 wt% acetic acid in water is contacted with 1250 kg of pure isopropyl ether as shown in **Figure Q3(b)**.

(i) Calculate the amount of total mass (M).

(2 marks)

(ii) Calculate the composition of mass fraction of acetic acid (x_{AM}) in the M stream.

(3 marks)

(iii) By trial-&-error method, identify a tie line that passes through M to intersect the raffinate at L_1 and the extract layer at V_1 in **Figure Q3 (b)(iii)**.

(12 marks)

(iv) Determine the composition of V_1 from the extract layer.

(3 marks)

(v) Determine the composition of L_1 from the raffinate layer.

(3 marks)

Q4 (a) List **FOUR (4)** types of separation processes.

(4 marks)

(b) A mixture of ethanol and benzene is separated in a network of distillation and membrane separation steps. In one intermediate step, a near-azeotropic liquid mixture of 10,000 kg/h of 25 wt% ethanol in benzene is fed to a pervaporation membrane consisting of a thin inonomeric film of perfluorosulfonic acid polymer cast on a porous Teflon support. The membrane is selective for ethanol such that the vapor permeate contains 65 wt% ethanol, while the non-permeate liquid contains 90 wt% benzene.

(i) Draw a flow diagram of the pervaporation step using the appropriate symbol from **Table Q4 (b)(i)** and include on the diagram all of the given information.

(8 marks)

(ii) Calculate the component flow rates in kg/h in the feed stream and in the two product streams and add the results on the diagram.

(8 marks)

(iii) Propose the separation operation that could be used to further purify the vapor permeate.

(5 marks)

-END OF QUESTIONS –

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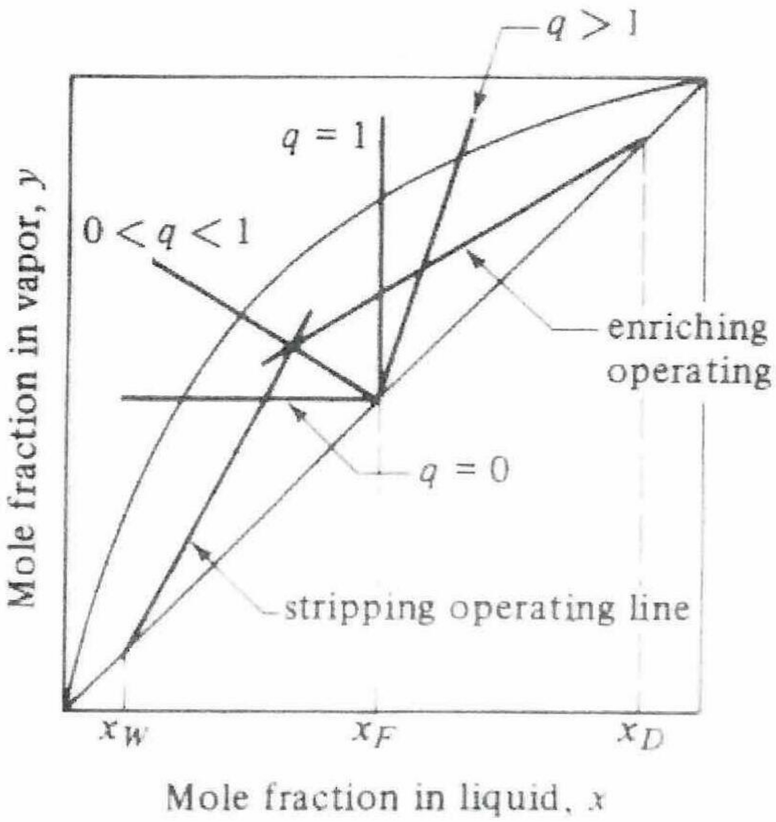

The q-line for various feed conditions:

$q = 0$ (saturated vapor)

$q = 1$ (saturated liquid)

$q > 1$ (subcooled liquid)

$q < 0$ (superheated vapor)

$0 < q < 1$ (mix of liquid and vapor)

Figure Q1 (b)

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Table Q1 (b)(i)

Vapor-Pressure and Equilibrium-Mole-Fraction Data for Benzene-Toluene System

Vapor Pressure						Mole Fraction Benzene at 101.325 kPa	
Temperature		Benzene		Toluene			
K	°C	kPa	mm Hg	kPa	mm Hg	x_A	y_A
353.3	80.1	101.32	760			1.000	1.000
358.2	85	116.9	877	46.0	345	0.780	0.900
363.2	90	135.5	1016	54.0	405	0.581	0.777
368.2	95	155.7	1168	63.3	475	0.411	0.632
373.2	100	179.2	1344	74.3	557	0.258	0.456
378.2	105	204.2	1532	86.0	645	0.130	0.261
383.8	110.6	240.0	1800	101.32	760	0	0

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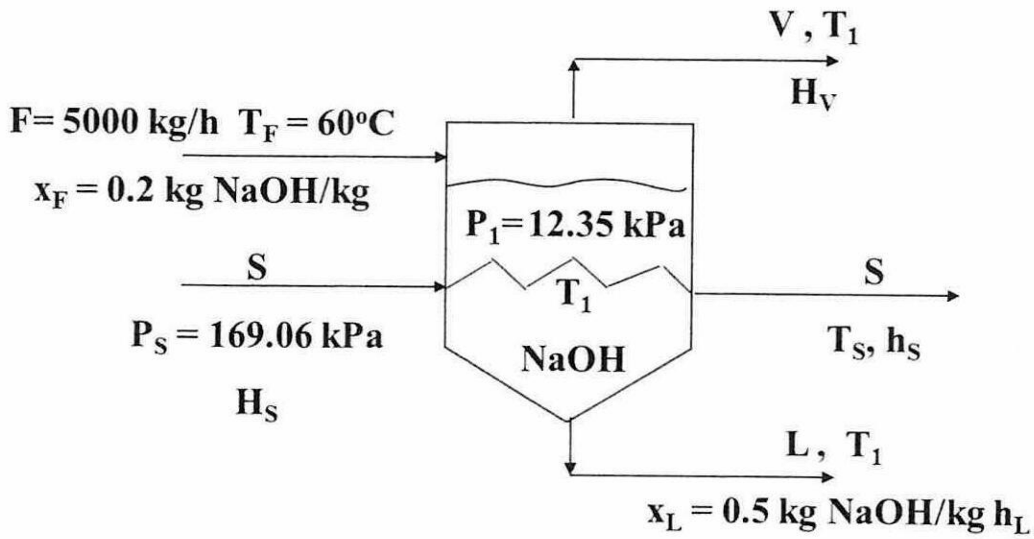

Figure Q2

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Table Q2

Properties of saturated steam and water

Temperature (°C)	Vapor Pressure (kPa)	Specific Volume (m^3/kg)		Enthalpy (kJ/kg)		Entropy ($kJ/kg \cdot K$)	
		Liquid	Sat'd Vapor	Liquid	Sat'd Vapor	Liquid	Sat'd Vapor
0.01	0.6113	0.0010002	206.136	0.00	2501.4	0.0000	9.1562
3	0.7577	0.0010001	168.132	12.57	2506.9	0.0457	9.0773
6	0.9349	0.0010001	137.734	25.20	2512.4	0.0912	9.0003
9	1.1477	0.0010003	113.386	37.80	2517.9	0.1362	8.9253
12	1.4022	0.0010005	93.784	50.41	2523.4	0.1806	8.8524
15	1.7051	0.0010009	77.926	62.99	2528.9	0.2245	8.7814
18	2.0640	0.0010014	65.038	75.58	2534.4	0.2679	8.7123
21	2.487	0.0010020	54.514	88.14	2539.9	0.3109	8.6450
24	2.985	0.0010027	45.883	100.70	2545.4	0.3534	8.5794
25	3.169	0.0010029	43.360	104.89	2547.2	0.3674	8.5580
27	3.567	0.0010035	38.774	113.25	2550.8	0.3954	8.5156
30	4.246	0.0010043	32.894	125.79	2556.3	0.4369	8.4533
33	5.034	0.0010053	28.011	138.33	2561.7	0.4781	8.3927
36	5.947	0.0010063	23.940	150.86	2567.1	0.5188	8.3336
40	7.384	0.0010078	19.523	167.57	2574.3	0.5725	8.2570
45	9.593	0.0010099	15.258	188.45	2583.2	0.6387	8.1648
50	12.349	0.0010121	12.032	209.33	2592.1	0.7038	8.0763
55	15.758	0.0010146	9.568	230.23	2600.9	0.7679	7.9913
60	19.940	0.0010172	7.671	251.13	2609.6	0.8312	7.9096

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Table Q2 (continued..)

Properties of saturated steam and water

Temperature (°C)	*Vapor Pressure (kPa)*	*Specific Volume (m^3/kg)*		*Enthalpy (kJ/kg)*		*Entropy (kJ/kg · K)*	
		Liquid	*Sat'd Vapor*	*Liquid*	*Sat'd Vapor*	*Liquid*	*Sat'd Vapor*
65	25.03	0.0010199	6.197	272.06	2618.3	0.8935	7.8310
70	31.19	0.0010228	5.042	292.98	2626.8	0.9549	7.7553
75	38.58	0.0010259	4.131	313.93	2635.3	1.0155	7.6824
80	47.39	0.0010291	3.407	334.91	2643.7	1.0753	7.6122
85	57.83	0.0010325	2.828	355.90	2651.9	1.1343	7.5445
90	70.14	0.0010360	2.361	376.92	2660.1	1.1925	7.4791
95	84.55	0.0010397	1.9819	397.96	2668.1	1.2500	7.4159
100	101.35	0.0010435	1.6729	419.04	2676.1	1.3069	7.3549
105	120.82	0.0010475	1.4194	440.15	2683.8	1.3630	7.2958
110	143.27	0.0010516	1.2102	461.30	2691.5	1.4185	7.2387
115	169.06	0.0010559	1.0366	482.48	2699.0	1.4734	7.1833
120	198.53	0.0010603	0.8919	503.71	2706.3	1.5276	7.1296
125	232.1	0.0010649	0.7706	524.99	2713.5	1.5813	7.0775
130	270.1	0.0010697	0.6685	546.31	2720.5	1.6344	7.0269
135	313.0	0.0010746	0.5822	567.69	2727.3	1.6870	6.9777
140	316.3	0.0010797	0.5089	589.13	2733.9	1.7391	6.9299
145	415.4	0.0010850	0.4463	610.63	2740.3	1.7907	6.8833
150	475.8	0.0010905	0.3928	632.20	2746.5	1.8418	6.8379
155	543.1	0.0010961	0.3468	653.84	2752.4	1.8925	6.7935

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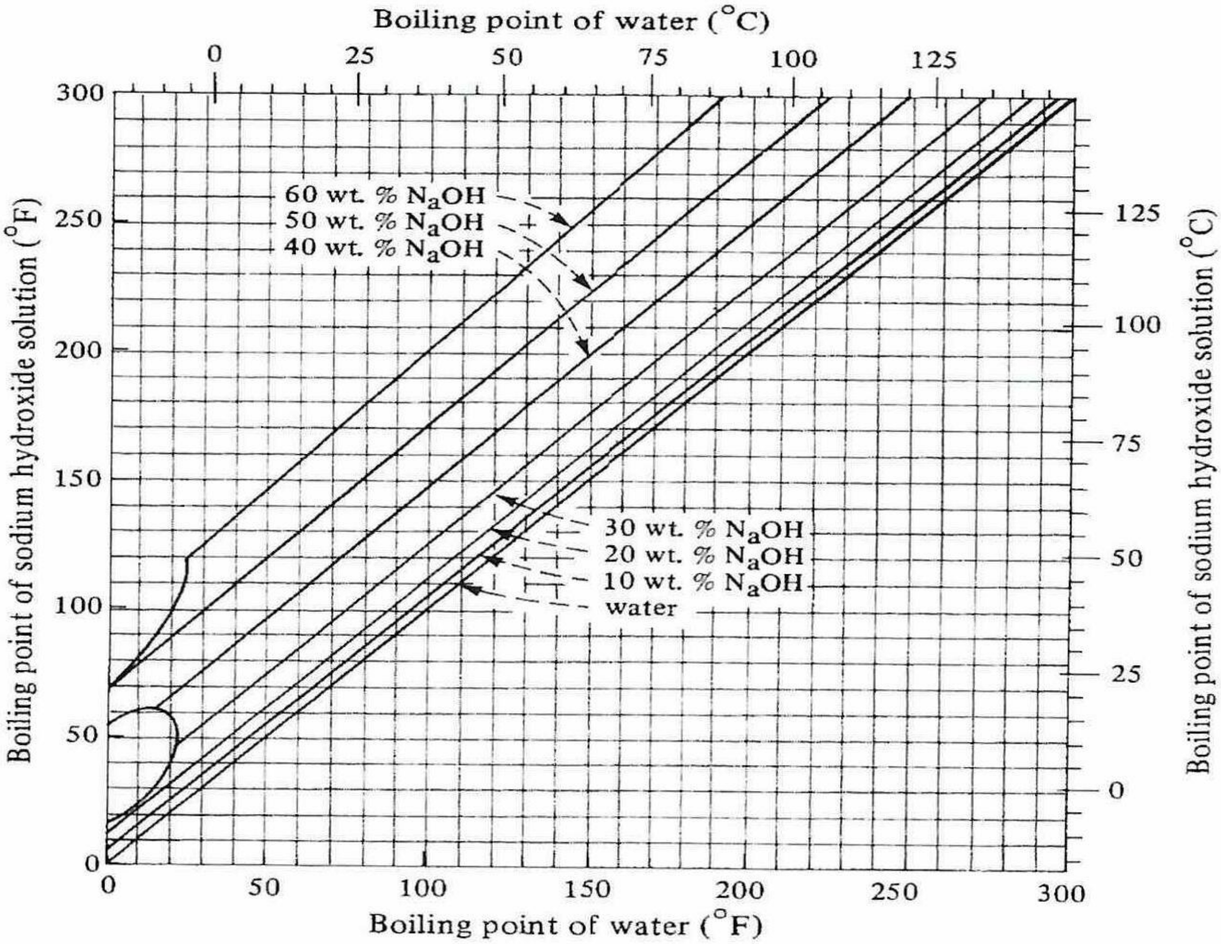

Figure Q2 (b)

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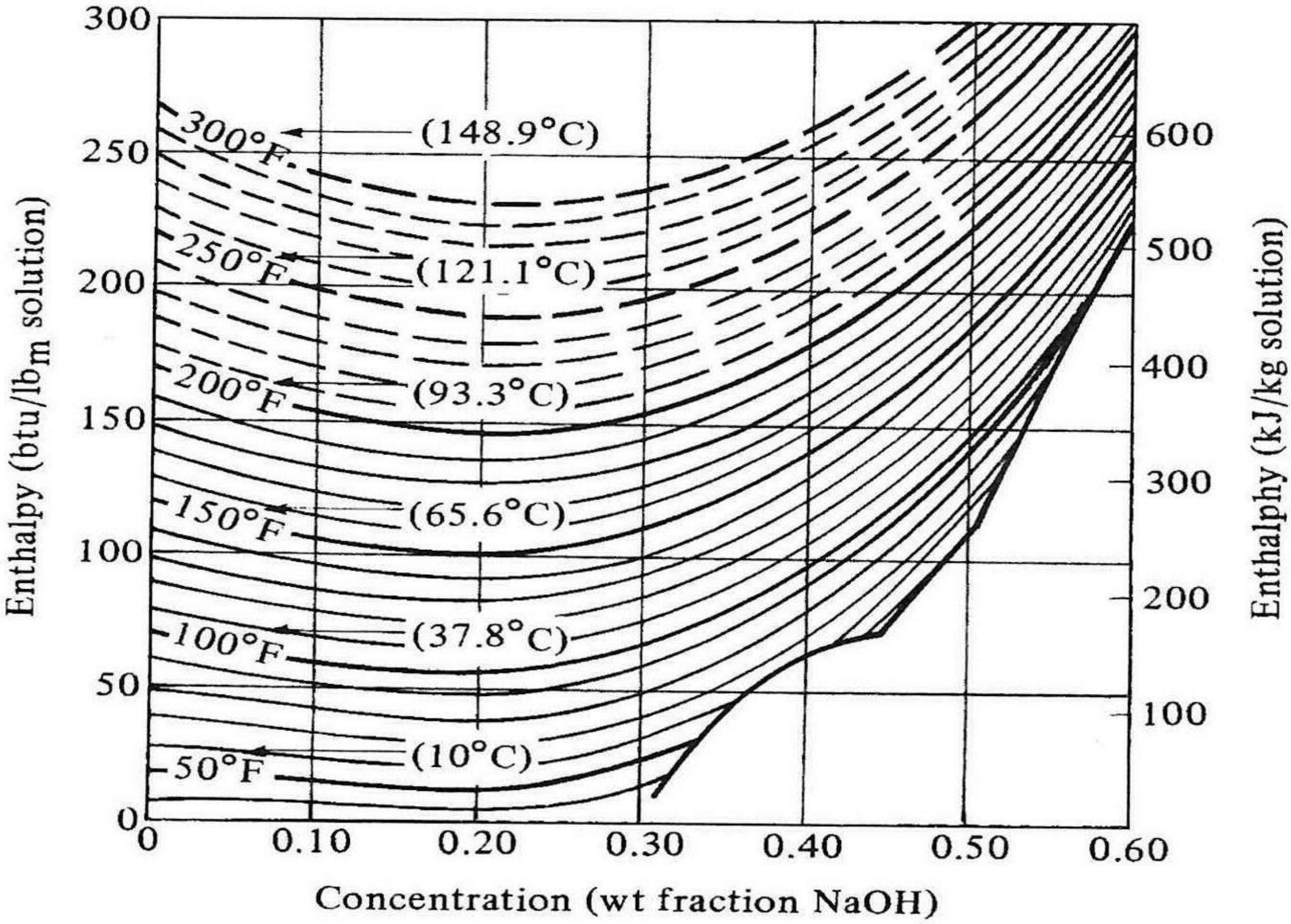

Figure Q2 (d)

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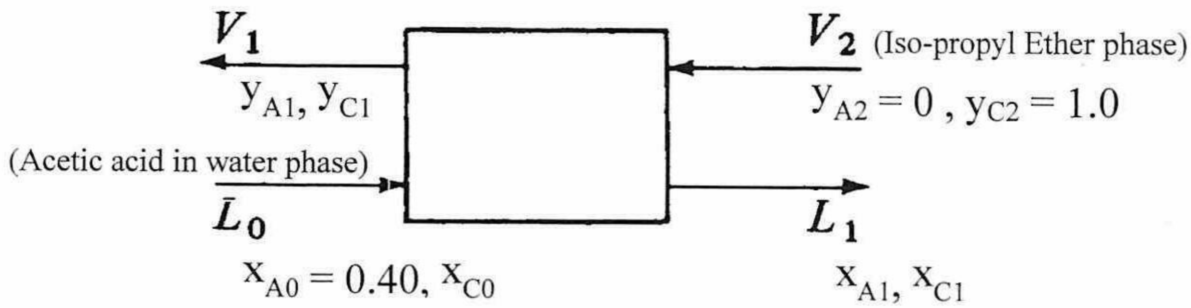

Figure Q3(b)

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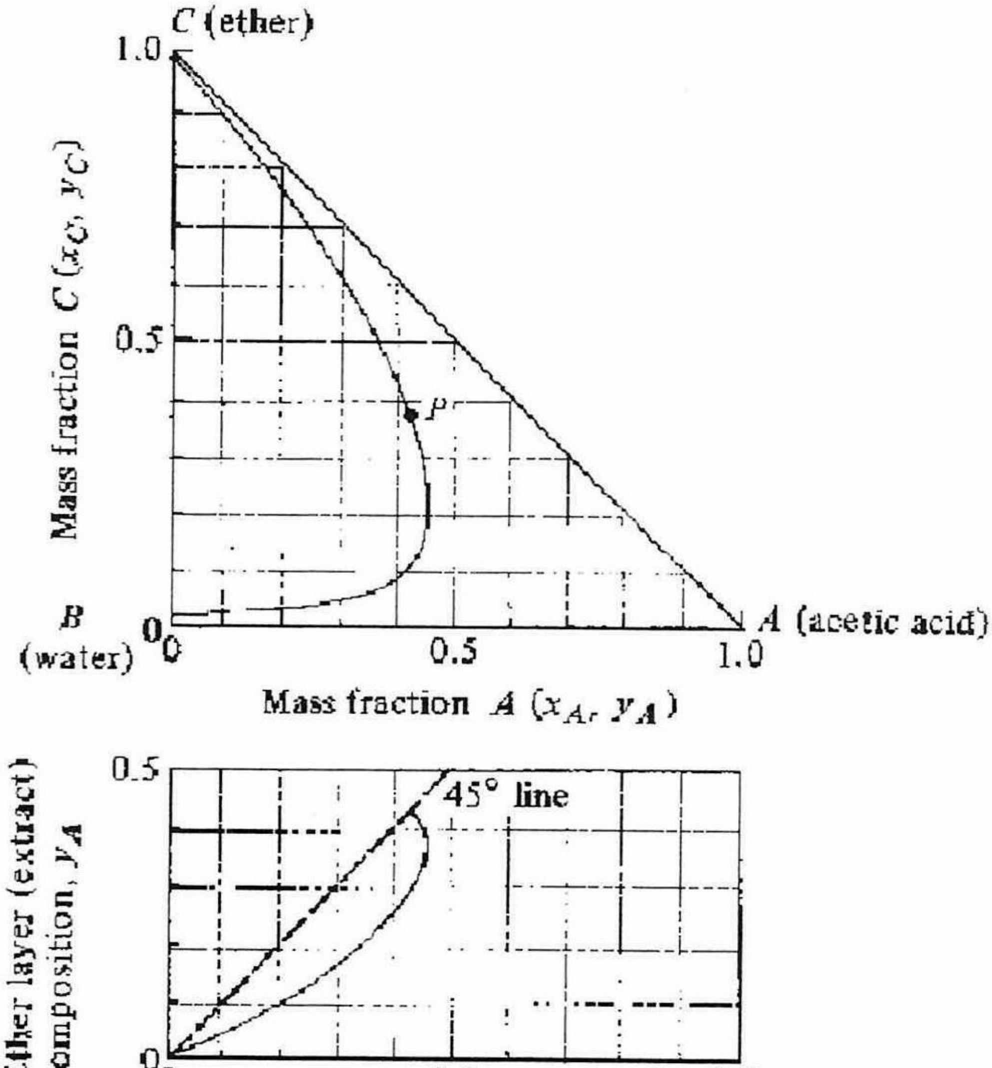

Figure Q3 (b)(iii)

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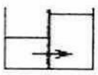
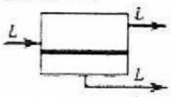
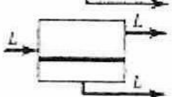
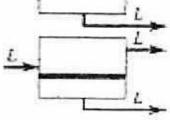
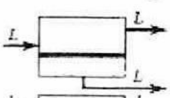
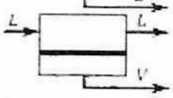
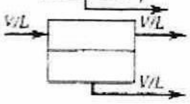
Table Q 4(b)(i)

Separation Operation	Symbol[a]	Initial or Feed Phase	Separating Agent	Industrial Example[b]
Osmosis (1)		Liquid	Nonporous membrane	—
Reverse osmosis* (2)		Liquid	Nonporous membrane with pressure gradient	Desalinization of sea water
Dialysis* (3)		Liquid	Porous membrane with pressure gradient	Recovery of caustic from hemicellulose
Microfiltration* (4)		Liquid	Microporous membrane with pressure gradient	Removal of bacteria from drinking water
Ultrafiltration* (5)		Liquid	Microporous membrane with pressure gradient	Separation of whey from cheese
Pervaporation* (6)		Liquid	Nonporous membrane with pressure gradient	Separation of azeotropic mixtures
Gas permeation* (7)		Vapor	Nonporous membrane with pressure gradient	Hydrogen enrichment
Liquid membrane (8)		Vapor and/or liquid	Liquid membrane with pressure gradient	Removal of hydrogen sulfide

*Design procedures are fairly well accepted.

[a]Single units are shown. Multiple units can be cascaded.

[b]Details of examples may be found in *Kirk-Othmer Encyclopedia of Chemical Technology*, 5th ed., John Wiley & Sons, New York (2004–2007).

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Formula sheet.

I. Equation used in distillation

$$y = \frac{R}{R+1}x + \frac{x_D}{R+1}$$

$$q = \frac{H_V - H_F}{H_V - H_L} = \frac{(H_V - H_L) + c_P(T_B - T_F)}{H_V - H_L}$$

$$y = \left(\frac{q}{q-1}\right)x - \frac{x_F}{q-1}$$

II. Heat and material balances for evaporators

$$Fh_F + S(H_S - h_S) = Lh_L + VH_V$$

$$\lambda = (H_S - h_S)$$

$$q = S\lambda = UA\Delta T = UA(T_S - T_1)$$

$$T_1 = T_{sat.\ at\ P1} + BPR$$

$$H_V = H_{sat.\ at\ P1} + 1.884(BPR)$$

III. Extraction

$$L_0 + V_2 = L_1 + V_1 = M$$

$$L_0x_{A0} + V_2y_{A2} = L_1x_{A1} + V_1y_{A1} = Mx_{AM}$$

$$L_0x_{C0} + V_2y_{C2} = L_1x_{C1} + V_1y_{C1} = Mx_{CM}$$