Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	PROCESS TECHNOLOGY
COURSE CODE	:	BNL 40203
PROGRAMME CODE	:	BNL
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

Q1 (a) List **THREE (3)** types of separation process.

(3 marks)

(b) The design and analysis of a liquid-liquid extractor involves more factors than for vapor-liquid operations because of complications introduced by the two liquids phases. Describe **THREE (3)** factors influencing the liquid-liquid extraction.

(6 marks)

(c) List **THREE (3)** main designs of plate/trays in distillation column.

(3 marks)

(d) The most common design of absorption systems is packed bed column (packed tower) and plate column. Outline **TWO (2)** advantages of the plate columns over packed tower.

(4 marks)

(e) Propose **THREE (3)** methods suitable for the separation of air into nitrogen and oxygen.

(9 marks)

Q2 A rectification column is fed 100 kg mol/h of a mixture of 50 mol % benzene and 50 mol % toluene at 101.32 kPa abs pressure. The feed is liquid at the boiling point. The distillate is to contain 90 mol % benzene and the bottoms 10 mol % benzene. The reflux ratio is 4.5:1. Data for the q-line is given in **Figure Q2**.

(a) Calculate the kg moles per hour distillate (D) and bottoms (W).

(8 marks)

(b) Determine the number of theoretical trays needed using the McCabe-Thiele method. Plot your answer using **Figure Q2(b)**.

(14 marks)

(c) Identify the feed tray number.

(3 marks)

Q3 A continuous single-effect evaporator concentrates 8000 kg/hr of a 1.0 wt% salt solution entering at 311.0 K (37.8 °C) to a final concentration of 2.0 wt%. The vapor space of the evaporator is at 101.325 kPa (1.0 atm abs) and the steam supplied is saturated at 143.3 kPa. The overall coefficient U = 1704 $W/m^2.K$. The steam table is shown in **Table Q3**.

(a) Calculate the amount of vapor and liquid products.

(4 marks)

(b) Calculate the latent heat (λ) of the steam.

(3 marks)

(c) Identify the enthalpy value of h_f and h_L, respectively.

(6 marks)

(d) Calculate the latent heat (H_v) of water.

(3 marks)

(e) Determine the steam (S) used during the process.

(4 marks)

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

(5 marks)

Q4 (a) Describe **THREE (3)** conditions when a liquid-liquid extraction is preferred over distillation.

(6 marks)

(b) A single-stage extraction is performed in which 400 kg of a solution containing 35 wt% acetic acid in water is contacted with 400 kg of pure isopropyl ether as shown in **Figure Q4 (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 Q4 (b)(iii)**.

(10 marks)

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

(2 marks)

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

(2 marks)

-END OF QUESTIONS –

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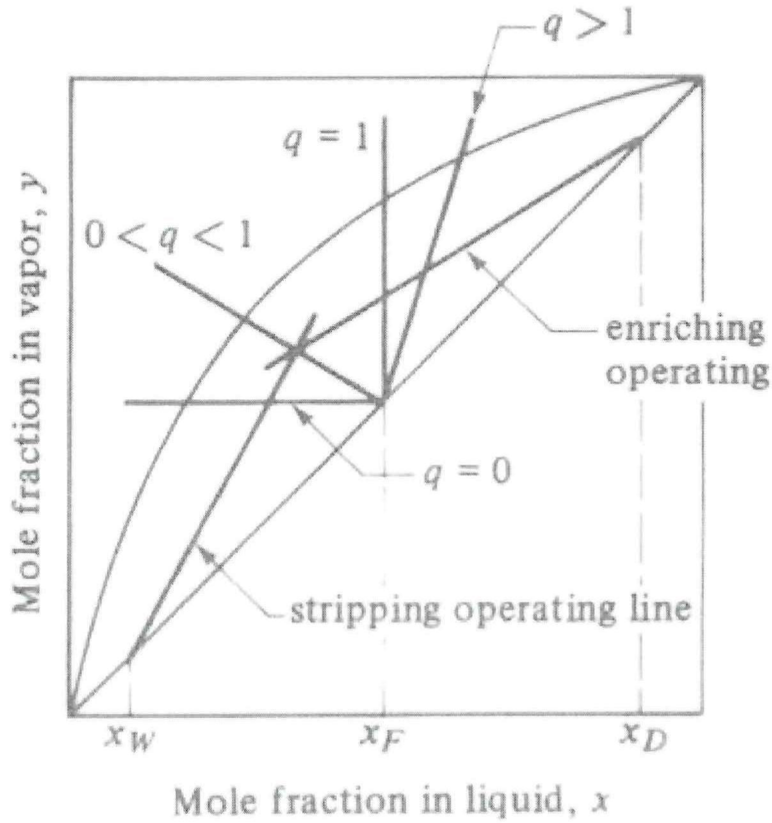

The q-line for various feed conditions:

$q = 0$ (saturated vapor)

$q = 1$ (saturated liquid)

$q > 1$ (subcooled liquid)

$q < 0$ (superheated vapor)

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

Figure Q2

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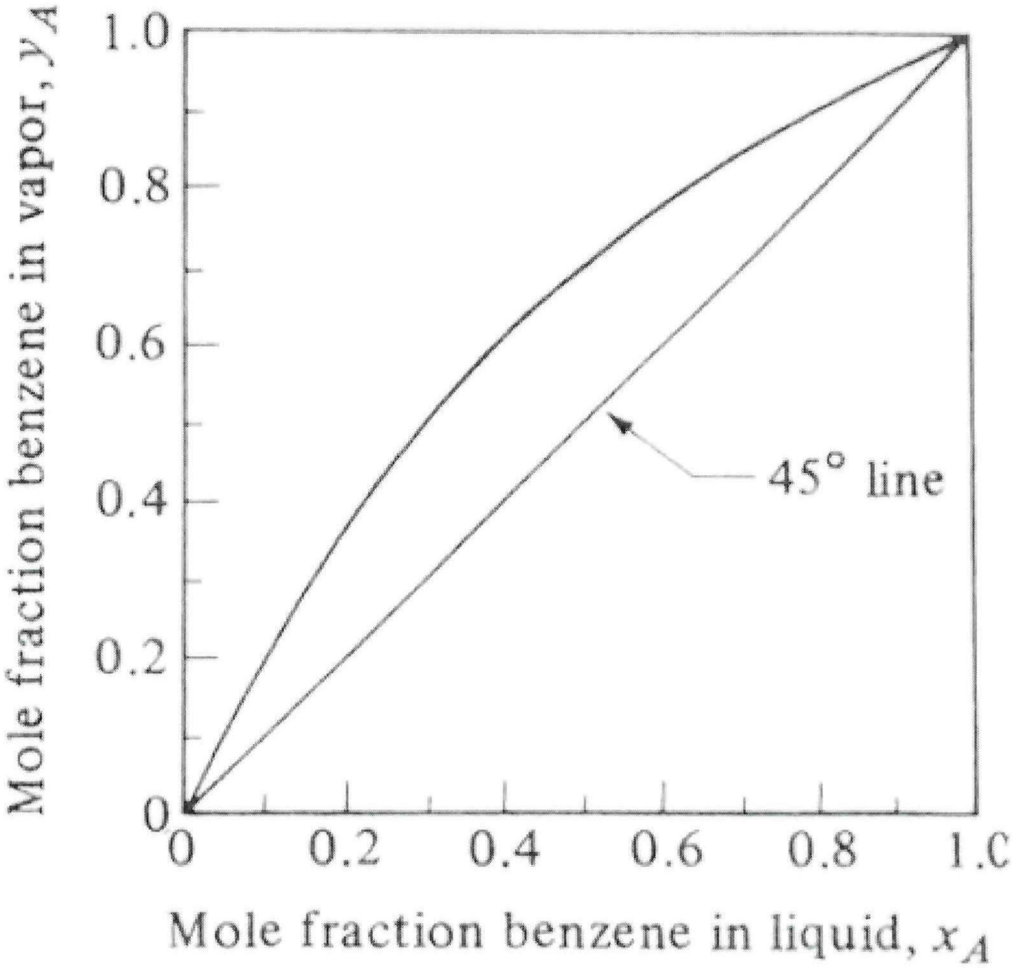

Figure Q2(b)

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Table Q3

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 Vapo
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
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

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Table Q3

Properties of Saturated Steam and Water (*continued...*)

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
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
160	617.8	0.0011020	0.3071	675.55	2758.1	1.9427	6.7502
165	700.5	0.0011080	0.2727	697.34	2763.5	1.9925	6.7078
170	791.7	0.0011143	0.2428	719.21	2768.7	2.0419	6.6663
175	892.0	0.0011207	0.2168	741.17	2773.6	2.0909	6.6256
180	1002.1	0.0011274	0.19405	763.22	2778.2	2.1396	6.5857
190	1254.4	0.0011414	0.15654	807.62	2786.4	2.2359	6.5079
200	1553.8	0.0011565	0.12736	852.45	2793.2	2.3309	6.4323
225	2548	0.0011992	0.07849	966.78	2803.3	2.5639	6.2503
250	3973	0.0012512	0.05013	1085.36	2801.5	2.7927	6.0730
275	5942	0.0013168	0.03279	1210.07	2785.0	3.0208	5.8938
300	8581	0.0010436	0.02167	1344.0	2749.0	3.2534	5.7045

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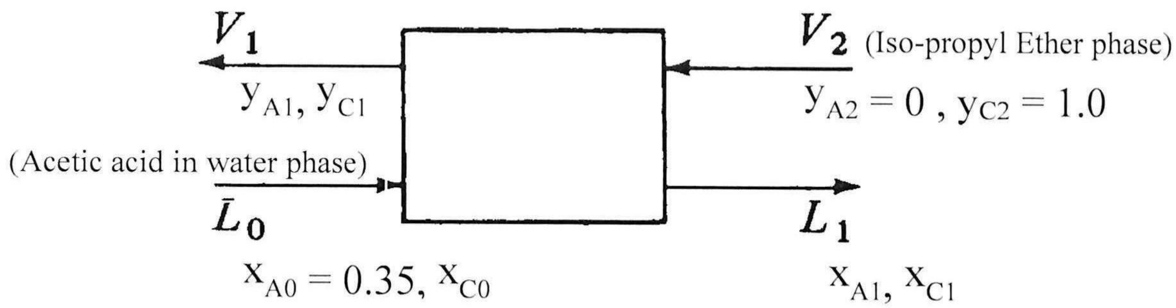

Figure Q4 (b)

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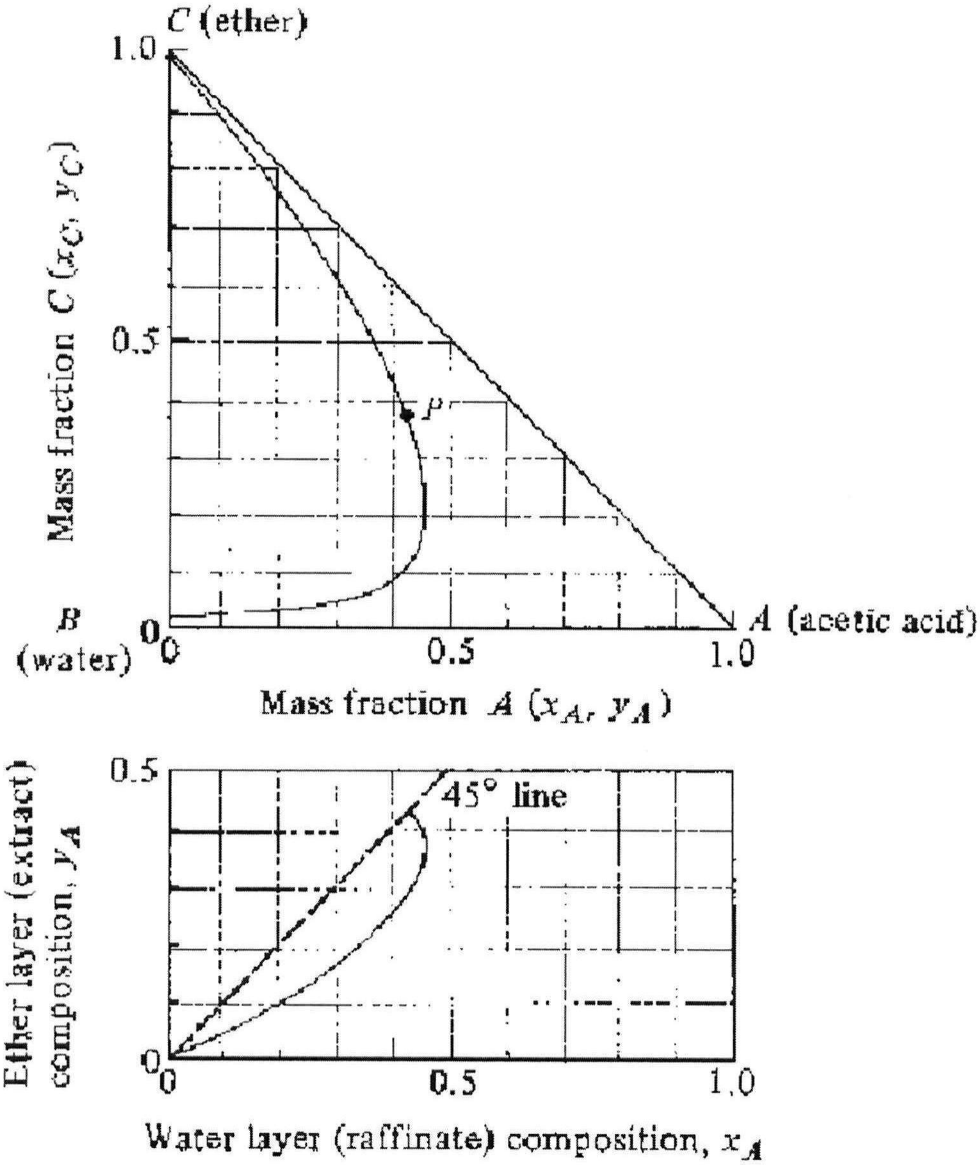

Figure Q4 (b)(iii)

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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

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

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

$$h_F = c_{PF}(T_F - T_{ref.})$$

$$h_L = c_{PL}(T_1 - T_{ref.})$$

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

III. Extraction

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

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

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