Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(TAKE HOME)
SEMESTER I
SESSION 2020/2021

COURSE NAME	:	PROCESS TECHNOLOGY
COURSE CODE	:	BNL 40203
PROGRAMME CODE	:	BNL
EXAMINATION DATE	:	JANUARY/FEBRUARY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS **ALL** QUESTIONS

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THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

Q1 A saturated liquid feed of 200 kg mol/h at the boiling point containing 42 mol% benzene and 58% toluene is to be fractionated at 101.32 kPa abs to give a distillate containing 95 mol% benzene and a bottom containing 2 mol% benzene. The reflux ratio used is 4.52:1. Data for the q-line is given in **Figure Q1**.

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

(4 marks)

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

(6 marks)

(c) Determine the number of theoretical trays needed using the McCabe-Thiele method. Plot your answer using x-y graph plotted in **Q1 (a)**.

(12 marks)

(d) Identify the feed tray number.

(3 marks)

Q2 An evaporator is used to concentrate 4500 kg/h of a 20% solution of NaOH in water entering at 60°C to a product of 40% 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 1800 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 40% concentrated solution by using **Figure Q2 (b)**.

(3 marks)

(c) Identify 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 used during the process.

(5 marks)

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

(4 marks)

Q3 (a) List **FIVE (5)** types of separation processes.

(5 marks)

(b) In evaporation, the vapor from a boiling liquid solution is removed and a more concentrated solution remains. Typical examples of evaporation are concentration of aqueous solutions of sugar, sodium chloride, sodium hydroxide, glycerol, milk, glue, and orange juice. Describe **THREE (3)** factors that affect the processing methods during evaporation.

(6 marks)

(c) Explain, using thermodynamic principles, why mixing pure chemicals to form a homogeneous mixture is a spontaneous process, while separation of that mixture into its pure species is not.

(6 marks)

(d) In the concentration of orange juice, a fresh extracted and strained juice containing 8.20 wt.% solids is fed to a vacuum evaporator. In the evaporator, water is removed and the solids content increased to 58% solids. For 2500 kg/h entering, calculate the amounts of the outlet streams of concentrated juice and water.

(8 marks)

Q4 (a) Briefly describe the following separation process:

(i) Liquid-liquid extraction
(ii) Absorption
(iii) Crystallization

(6 marks)

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

(6 marks)

(c) Discuss why the separation of a stream containing 10 wt% acetic acid in water might be more economical by liquid liquid extraction with ethyl acetate than by distillation.

(5 marks)

(d) Identify the appropriate separation method for the following industrial processes:

(i) Separation of soymilk from soybean using water.
(ii) Separation of benzene, toluene and xylene (BTX) from naphtha as the feed.

(4 marks)

(e) Identify **TWO (2)** methods suitable for the separation of air into nitrogen and oxygen.

(4 marks)

-END OF QUESTIONS –

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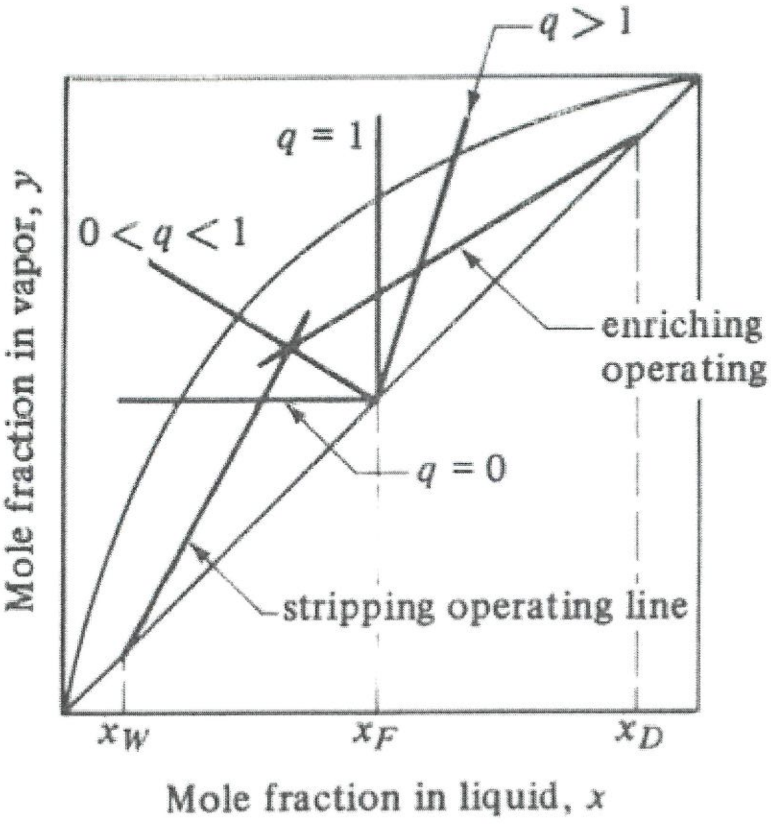

The q-line for various feed conditions:

$q = 0$ (saturated vapor)

$q = 1$ (saturated liquid)

$q > 1$ (subcooled liquid)

$q < 0$ (superheated vapor)

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

Figure Q1

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Table Q1 (a)

Vapor-Pressure and Equilibrium-Mole-fraction Data for Benzene-Toluence System

Temperature		Vapor Pressure: Benzene		Vapor Pressure: Toluene		Mole Fraction Benzene at 101.325 kPa	
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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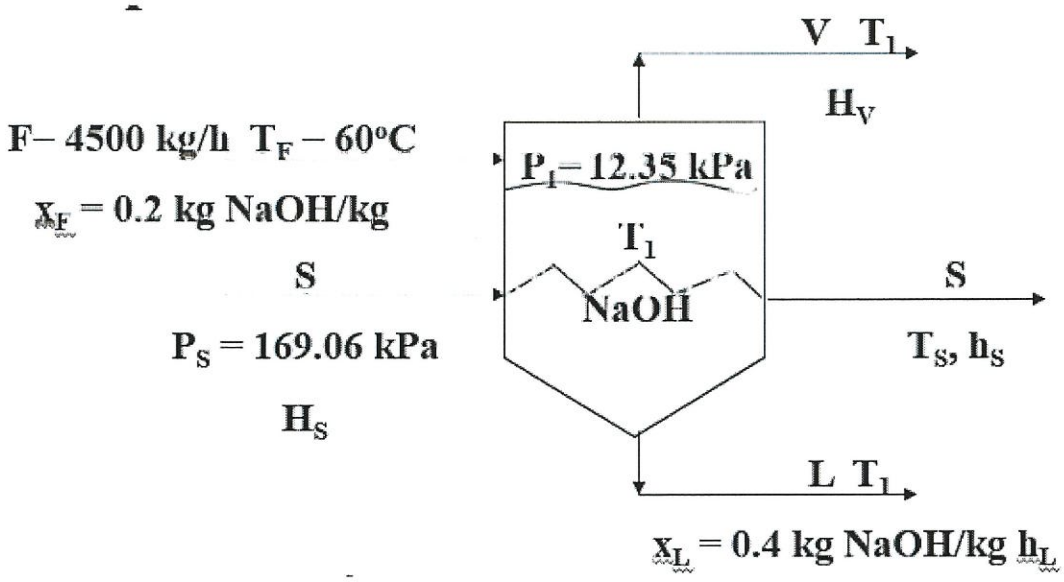

Figure Q2

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Table Q2

Properties of saturated steam and water

Temperature (°C)	Vapor Pressure (kPa)	Specific Volume (m³/kg)		Enthalpy (kJ/kg)		Entropy (kJ/kg · 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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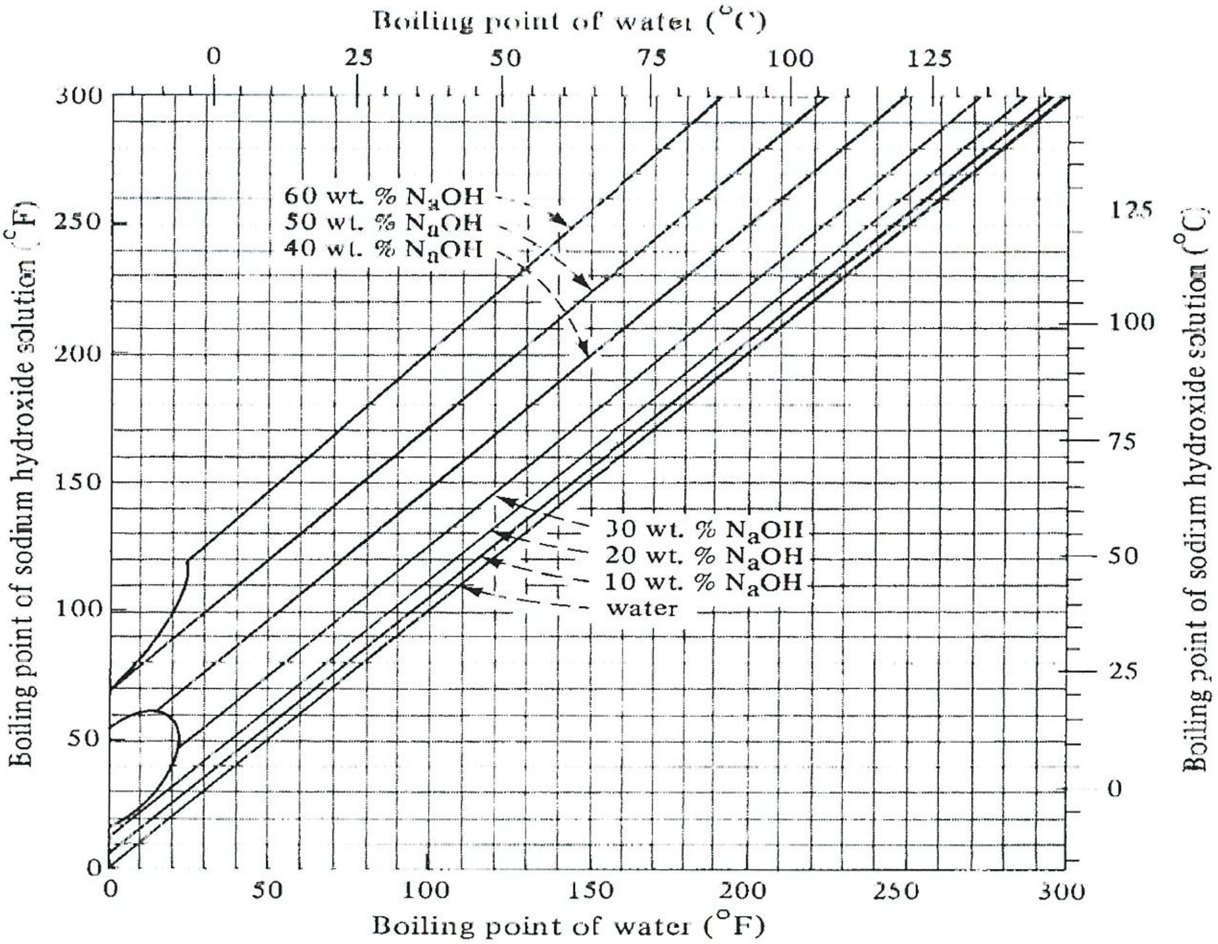

Figure Q2 (b)

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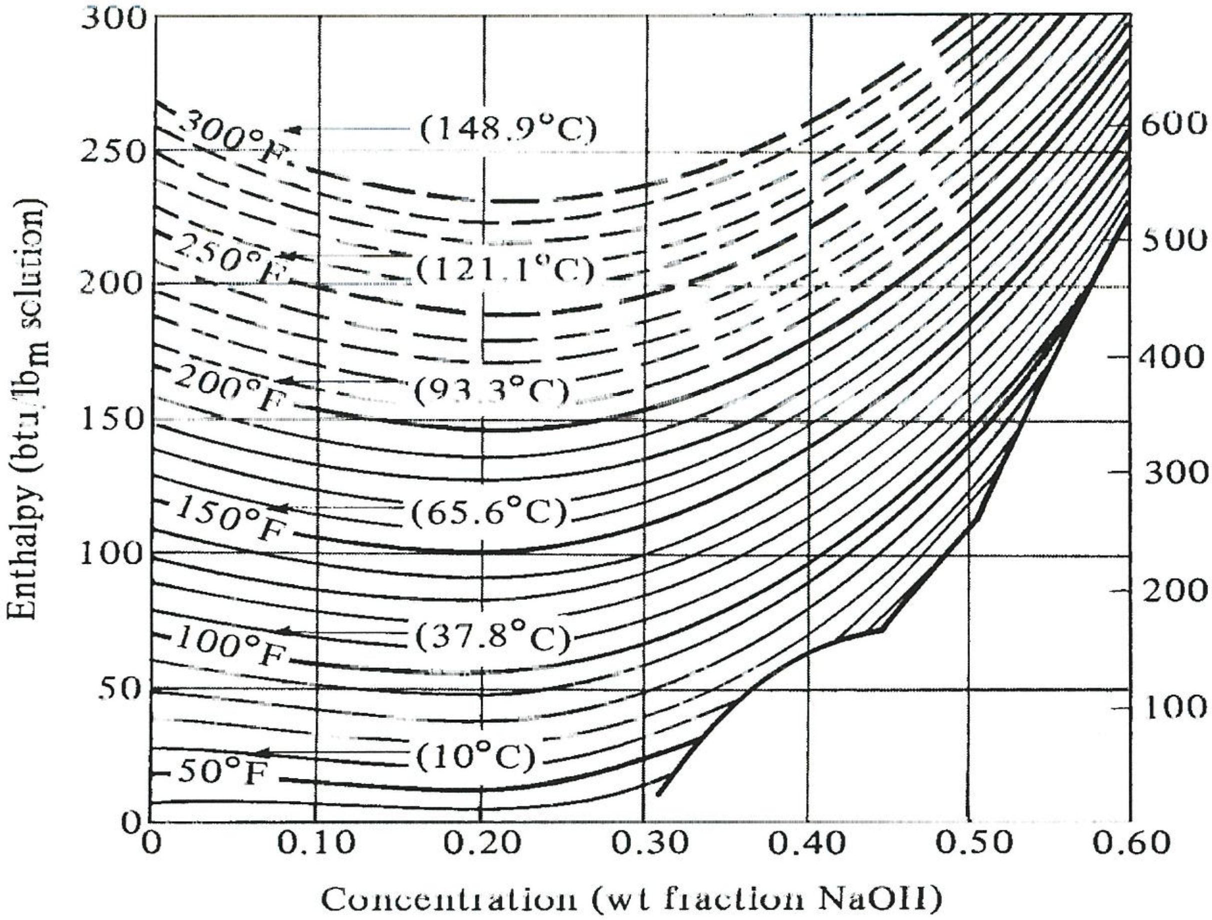

Figure Q2 (d)