UNIVERSITY COLLEGE TATI

UNIVERSITY COLLEGE TATI (UC TATI)

FINAL EXAMINATION QUESTION BOOKLET	
COURSE CODE	: BCE 2214
COURSE	: UNIT OPERATION 1
SEMESTER/SESSION	: 2-2023/2024
DURATION	: 3 HOURS

Instructions:

1. This booklet contains 5 questions. Answer **ALL** questions.
2. All answers should be written in answer booklet.
3. Write legibly and draw sketches wherever required.
4. If in doubt, raise your hands and ask the invigilator.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO
YOU ARE PERMITTED TO BRING ONE SHEET, EQUIVALENT TO TWO PAGES ON AN A4-SIZED PAPER

THIS BOOKLET CONTAINS 11 PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

A gas mixture with a total pressure of 2.026 x 10^5 Pa, consisting of air and SO_2, is brought into contact with pure water in a single-stage equilibrium mixer at a temperature of 293 K. The partial pressure of SO_2 in the original gas is 1.52 x 10^4 Pa. The inlet gas contains a total of 5.70 kg mol, while the inlet water contains a total of 2.20 kg mol. The exit gas and liquid leaving the mixer are in equilibrium. Figure 1 provides the equilibrium data required to answer the following questions:

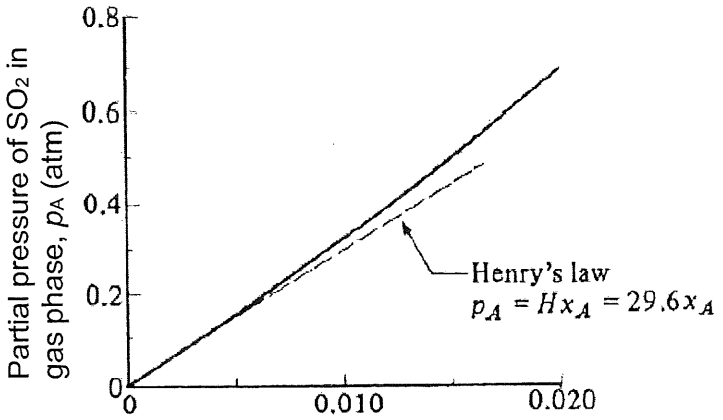

Figure 1: Equilibrium plot for SO_2–water system at 293 K (20°C).

a) Illustrate the diagram for this process (3 marks)

b) Convert total pressure to atm unit (2 marks)

c) Find the value of y_{A2} (2 marks)

d) From Henry's Law equation in Figure 1, employ the equation of y_{A1} in terms of x_{A1} (3 marks)

e) Compute x_{A1}, y_{A1}, L1 and V1 (10 marks)

QUESTION 2

An evaporator with an area of 83.6 m^2 and a heat transfer coefficient (U) of 2270 $W/m^2.K$ is employed to generate distilled water for a boiler feed. The feed to the evaporator is tap water, which contains 400 ppm dissolved solids and is at a temperature of 15.6°C. The evaporator operates at an absolute pressure of 1 atm. Saturated steam at a temperature of 115.6°C is accessible for heating. The outlet liquid contains 800 ppm solids. Assume: Datum temperature is 100°C and the heat capacity of feed is 4.188 kJ/kg.K.

a) Describe the process with suitable diagram (5 marks)
b) Interpret the mass balance and find V in terms of F (3 marks)
c) Discover the latent heat of water and steam from the steam table (4 marks)
d) Compute the value of F (kg/h) and V (kg/h distilled H_2O) (8 marks)

QUESTION 3

a) The air entering a dryer has a temperature of 65.6°C (150°F) and a dew point of 15.6°C (60°F).

i) Use humidity chart to solve the actual humidity in SI unit. (2 marks)
ii) Use humidity chart to compute percentage humidity. (2 marks)
iii) Solve the humid volume of this mixture in SI unit (4 marks)
iv) Solve humid heat in SI unit (4 marks)

b) The air in a room has a humidity H of 0.021 kg H_2O/kg dry air at 32.2°C and 101.3 kPa with a partial pressure, p_A = 3.309 kPa. Compute the following:

i) Percentage humidity H_P (6 marks)
ii) Percentage relative humidity H_R (2 marks)

QUESTION 4

An enriching tower is fed 100 kg mol/h of a saturated vapor feed containing 40 mol % benzene (A) and 60 mol % toluene (B) at 101.32 kPa abs. The distillate is to contain 90 mol % benzene, while the bottom contain 27.5 mol % benzene. The reflux ratio is set at 4.0:1.

a) Compute the kg mol/h distillate, D. (3 marks)

b) Compute the kg mol/h bottoms, W. (2 marks)

c) Solve q and slope. Justify your answer. (3 marks)

d) Sketch q line and enriching operating line in equilibrium diagram for benzene-toluene at 101.32 kPa (1 atm) in page 11 (6 marks)

e) Compute the number of theoretical trays needed. (6 marks)

QUESTION 5

a) Describe three (3) applications of each, leaching and liquid-liquid extraction in chemical process industries (6 marks)

b) A slurry of flaked soybeans weighing a total of 100 kg contains 75 kg of inert solids and 25 kg of solution with 10 wt % oil and 90 wt % solvent hexane. This slurry is contacted with 100 kg of pure hexane in a single stage so that the value of N for the outlet underflow is 1.5 kg insoluble solid/kg solution retained. The process flow is shown in Figure 2.

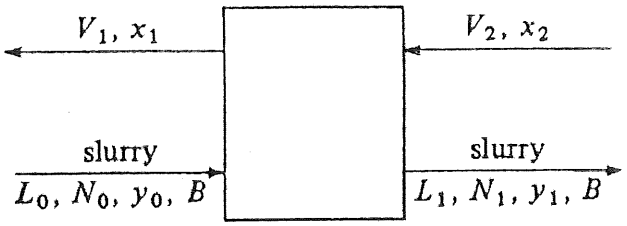

Figure 2: Process Flow

i) Show the amount of V_2, x_{A2}, x_{c0}, x_{c2}, L_0, y_{A0} in Figure 2 (6 marks)

ii) Compute total flow rate (M), ratio of solid to solution (N_0), x_{AM} and N_M (8 marks)

----------End of question----------

ATTACHMENTS

$$p_A = Hx_A$$

$$y_A = H'x_A$$

$$H' = H/P$$

$$L'\left(\frac{x_{A0}}{1-x_{A0}}\right) + V'\left(\frac{y_{A2}}{1-y_{A2}}\right) = L'\left(\frac{x_{A1}}{1-x_{A1}}\right) + V'\left(\frac{y_{A1}}{1-y_{A1}}\right)$$

$$V' = V(1-y_A)$$

$$L_1 = \frac{L'}{1-x_{A1}}$$

$$V_1 = \frac{V'}{1-y_{A1}}$$

$$F = L + V$$

$$h_F = c_{pF}(T_F - T_1)$$

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

$$Fh_F + S\lambda = Lh_L + VH_V$$

$$q = S(\lambda) = UA\,\Delta T$$

$$H_S = \frac{18.02}{28.97}\,\frac{p_{AS}}{P - p_{AS}}$$

$$H_P = 100\frac{H}{H_S}$$

$$H_R = 100\frac{p_A}{p_{AS}}$$

$$c_S \text{ kJ/kg dry air} \cdot \text{K} = 1.005 + 1.88H \qquad \text{(SI)}$$

$$c_S \text{ btu/lb}_\text{m} \text{ dry air} \cdot {}^\circ\text{F} = 0.24 + 0.45H \qquad \text{(English)}$$

$$v_H \text{ m}^3\text{/kg dry air} = \frac{22.41}{273} T \text{ K} \left(\frac{1}{28.97} + \frac{1}{18.02} H \right)$$

$$= \left(2.83 \times 10^{-3} + 4.56 \times 10^{-3} H\right) T \text{ K}$$

$$v_H \text{ ft}^3\text{/lb}_\text{m} \text{ dry} = \frac{359}{492} T^\circ\text{R} \left(\frac{1}{28.97} + \frac{1}{18.02} H \right)$$

$$= \left(0.0252 + 0.0405H\right) T^\circ\text{R}$$

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

$$L_0 y_{A0} + V_2 x_{A2} = L_1 y_{A1} + V_1 x_{A1} = M x_{AM}$$

$$B = N_0 L_0 + 0 = N_1 L_1 + 0 = N_M M$$

Table A.2-9a. *Properties of Saturated Steam and Water (Steam Table), SI Units*

		Specific Volume (m^3/kg)		*Enthalpy (kJ/kg)*		*Entropy (kJ/kg · K)*	
Temperature (°C)	*Vapor Pressure (kPa)*	*Liquid*	*Sat'd Vapor*	*Liquid*	*Sat'd Vapor*	*Liquid*	*Sat'd Vapor*
0.01	0.6110	0.0010002	206.14	0.00	2501.4	0.00	9.1555
10	1.2260	0.0010003	106.31	42.02	2519.2	0.1511	8.8998
15	1.7051	0.0010009	77.881	62.98	2528.4	0.2245	8.7804
20	2.3371	0.0010018	57.761	83.92	2537.5	0.2965	8.6661
25	3.169	0.0010030	43.341	104.84	2546.5	0.3673	8.5568
30	4.246	0.0010044	32.882	125.75	2555.6	0.4368	8.4521
35	5.6236	0.0010060	25.208	146.64	2564.6	0.5052	8.3518
40	7.384	0.0010079	19.517	167.54	2573.5	0.5724	8.2557
45	9.593	0.0010099	15.253	188.44	2582.5	0.6386	8.1634
50	12.349	0.0010121	12.028	209.34	2591.3	0.7038	8.0749
55	15.759	0.0010145	9.5649	230.24	2600.1	0.7680	7.9899
60	19.940	0.0010171	7.6677	251.15	2608.8	0.8312	7.9082
65	25.03	0.0010199	6.1938	272.08	2617.5	0.8935	7.8296
70	31.19	0.0010228	5.0397	293.02	2626.1	0.9550	7.7540
75	38.58	0.0010258	4.1291	313.97	2634.6	1.0156	7.6812
80	47.39	0.0010290	3.4053	334.95	2643.0	1.0754	7.6110
85	57.83	0.0010324	2.8259	355.95	2651.3	1.1344	7.5434
90	70.14	0.0010359	2.3591	376.97	2659.5	1.1927	7.4781
95	25.03	0.0010396	1.9806	398.02	2667.6	1.2502	7.4150
100	31.19	0.0010435	1.6719	419.10	2675.6	1.3070	7.3541

105	38.58	0.0010474	1.4185	440.21	2683.4	1.3632	7.2951
110	47.39	0.0010516	1.2094	461.36	2691.1	1.4187	7.2380
115	169.06	0.0010559	1.0359	482.55	2698.6	1.4735	7.1827
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
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

Source: Data from *ASME Steam Tables, Compact Edition*, © 2006 ASME.

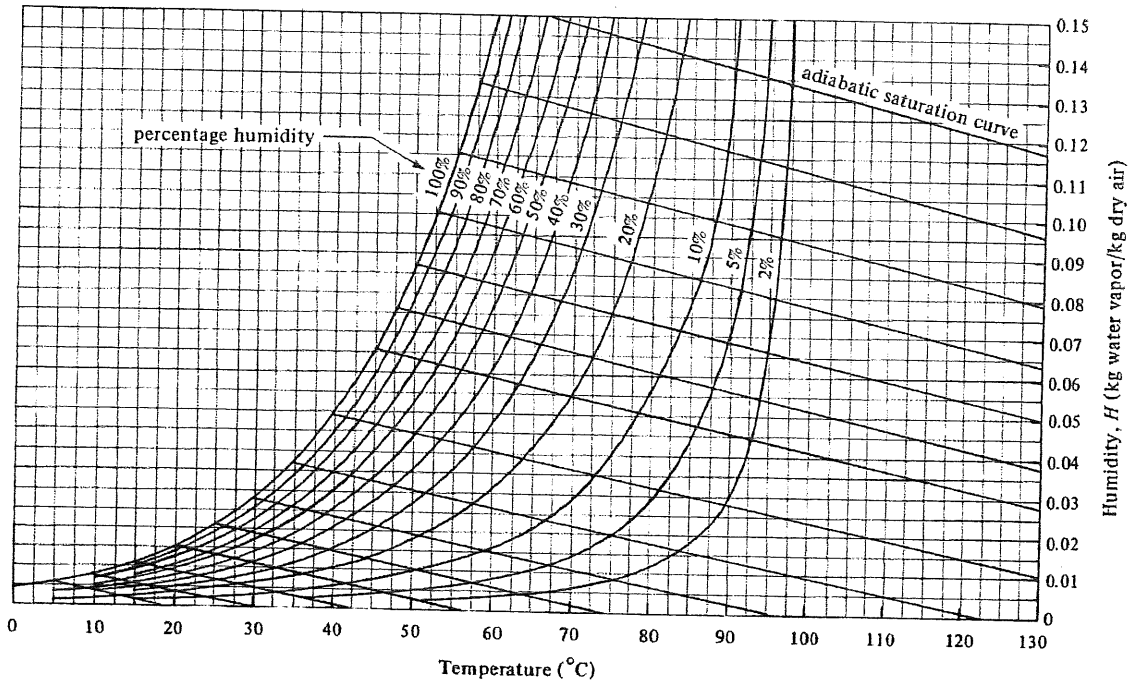

Figure 33.3-2. *Humidity chart for mixtures of air and water vapor at a total pressure of 101.325 kPa (760 mmHg). From R. E. Treybal,* Mass-Transfer Operations, *3rd ed. New York: McGraw-Hill Book Company, 1980. With permission.*

Table A.1-19. *Temperature*

0°C = 32°F (freezing point of water)
1.0 K = 1.0°C = 1.8°F = 1.8°R (Rankine)
°F = 32 + 1.8 (°C)
°C = (1/1.8)(°F – 32)
°R = °F + 459.67
K = °C + 273.15
100°C = 212°F = 373.15 K = 671.67°R
0°C = 32°F = 273.15 K = 491.67°R
–273.15°C = –459.67°F = 0 K = 0°R (absolute zero)

Reminder: Plot q line and enriching operating line in this diagram and submit together with your answer scipt.