CONFIDENTIAL

UNIVERSITY COLLEGE TATI (UC TATI)

FINAL EXAMINATION QUESTION BOOKLET	
COURSE CODE	: BCE 2214
COURSE	: UNIT OPERATIONS 1
SEMESTER/SESSION	: 2-2024/2025
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 TWO SHEET, EQUIVALENT TO FOUR PAGES ON AN A4-SIZED PAPER

THIS BOOKLET CONTAINS 9 PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

An evaporator with an area of 149.3 m^2 is employed to concentrates 9072 kg/h of salt solution. The feed contains 1.0 wt% salt solution entering at 311.0 K (37.8°C). 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 outlet solution contains 1.5 wt% salt solution. Given the heat capacity of feed is 4.14 kJ/kg.K. Assume that the solution, since it is diluted has the same boiling point as water.

a) Describe the process with suitable diagram (5 marks)
b) Employ mass balance and find L and V (4 marks)
c) Discover the latent heat of water and steam from the steam table (4 marks)
d) Compute the value of the steam used (S) (3 marks)
e) Solve the overall coefficient (U) in correct unit (4 marks)

QUESTION 2

a) An air–water vapor mixture going to a drying process has a dry bulb temperature of 57.2°C and a humidity of 0.030 kg H_2O/kg dry air.

i) Use humidity chart to solve the percentage humidity, saturation humidity at 57.2°C and dew point. Describe the method. (7 marks)

ii) Use appropriate equations to compute humid heat, and humid volume. (4 marks)

b) The air in a room is at 37.8°C and a total pressure of 101.3 kPa abs containing water vapor with a partial pressure is 3.59 kPa. Compute the following in SI unit:

i) Humidity (2 marks)
ii) Saturation humidity (3 marks)
iii) Percentage humidity (2 marks)
iv) Percentage relative humidity (2 marks)

QUESTION 3

To achieve a 90% absorption of hydrogen sulfide (H_2S) in a gas stream containing 1.0 mol % H_2S in air in a countercurrent stage tower, it's necessary to determine the number of theoretical stages required. The total inlet gas flow to the tower is 30.0 kg mol/h, and the total inlet pure water flow for absorption is 90 kg mol H_2O/h. The process operates isothermally at 300 K and a total pressure of 101.3 kPa. The equilibrium relationship for hydrogen sulfide (A) in the gas-liquid phase is given by $y_A = 2.53x_A$.

a) Compute amount of entering H_2S and entering air (4 marks)

b) Compute amount of H_2S leaving in V_1 and in L_1 (4 marks)

c) *Find* y_{A1} *and* x_{AN} (4 marks)

d) Use the Kremser analytical equation to determine the number theoretical stages required for this separation (8 marks)

QUESTION 4

An enriching distillation column is supplied with a saturated vapor stream of 100 kg mol/h, comprising 40 mol % component X (A) and 60 mol % component Y (B) at 101.32 kPa absolute pressure. The objective is to produce a distillate stream with 90 mol % component X, while the bottom stream should contain 27.5 mol % component X. The reflux ratio is adjusted to 4:1.

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 component X and Y at 101.32 kPa (1 atm) in page 9 (6 marks)

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

QUESTION 5

In a single-stage extraction of olive oil from crushed olives using ethanol, 100 kg of olives containing 20 wt % oil is extracted with 100 kg of fresh ethanol solvent. The value of N for the pulp underflow remains constant at 1.5 kg insoluble solid/kg solution retained.

a) Solve B, L_o and N_o (6 marks)

b) Compute the total flowrate M, x_{AM} and N_M (6 marks)

c) Show the graphical solution of single stage leaching (4 marks)

d) Compute L_1 and V_1 (4 marks)

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

ATTACHMENTS

$$p_A = Hx_A$$

$$y_A = H'x_A$$

$$H' = H/P$$

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

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

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

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

$$F = L + V$$

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

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

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

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

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

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

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

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

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

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

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

$$\upsilon_H \text{ ft}^3/1\text{b}_m \text{ dry} = \frac{359}{492} T°\text{R}\left(\frac{1}{28.97} + \frac{1}{18.02} H\right)$$

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

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

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

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

$$A_1 = \frac{L}{mV} = \frac{L_0}{mV_1}$$

$$A_n = \frac{L_N}{mV_{N+1}}$$

$$A = \sqrt{A_1 A_N}$$

$$N = \frac{\ln\left[\frac{y_{N+1} - mx_0}{y_1 - mx_0}\left(1 - \frac{1}{A}\right) + \frac{1}{A}\right]}{\ln A}$$

A.1-9 Power

1 hp = 0.74570 kW
1 hp = 550 ft · lb_f/s
1 hp = 0.7068 btu/s
1 watt (W) = 14.340 cal/min
1 btu/h = 0.29307 W (watt)
1 J/s (joule/s) = 1 W

A.1.19 Temperature

F = 32 + 1.8C
K= C + 273.2
R= F + 460

A.1-8 Pressure

1 bar = 1×10^5 Pa (pascal) = 1×10^5 N/m^2
1 psia = 1 lb_f/in.^{2}
1 psia = 2.0360 in. Hg at 0°C
1 psia = 2.311 ft H_2O at 70°F
1 psia = 51.715 mm Hg at 0°C (ρ_{Hg} = 13.5955 g/cm^3)
1 atm = 14.696 psia = 1.01325×10^5 N/m^2 = 1.01325 bar
1 atm = 760 mm Hg at 0°C = 1.01325×10^5 Pa
1 atm = 29.921 in. Hg at 0°C
1 atm = 33.90 ft H_2O at 4°C
1 psia = 6.89476×10^4 g/cm · s^2
1 psia = 6.89476×10^4 dyn/cm^2
1 dyn/cm^2 = 2.0886×10^{-3} lb_f/ft^2
1 psia = 6.89476×10^3 N/m^2 = 6.89476×10^3 Pa
1 lb_f/ft^2 = 4.7880×10^2 dyn/cm^2 = 47.880 N/m^2
1 mm Hg (0°C) = 1.333224×10^2 N/m^2 = 0.1333224 kPa

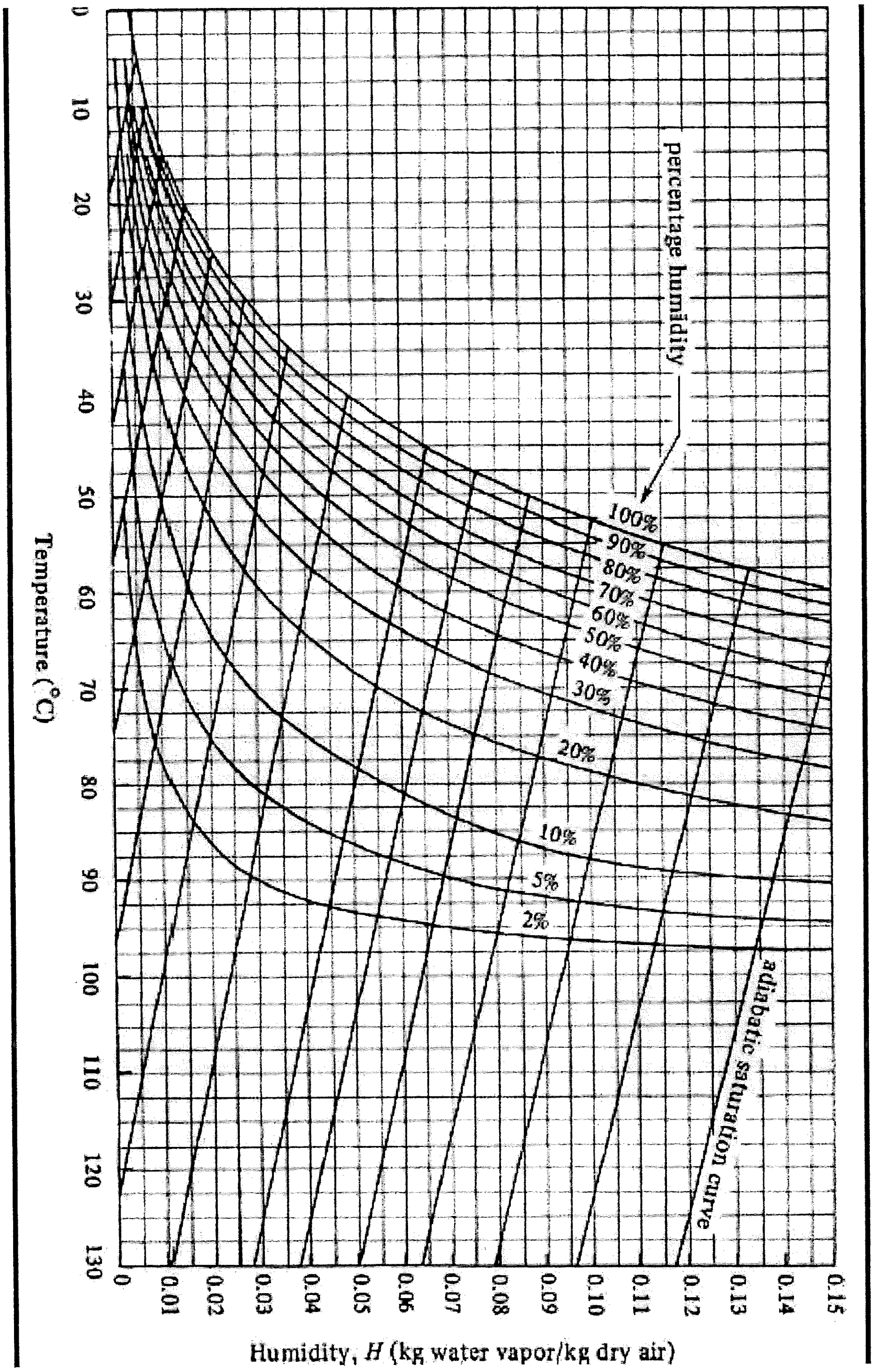
A.2-9 Properties of Saturated Steam and Water (Steam Table), SI Units

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
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

A.2-9 SI Units, *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

Source: Abridged from J. H. Keenan, F. G. Keyes, P. G. Hill, and J. G. Moore, *Steam Tables—Metric Units*. New York: John Wiley & Sons, Inc., 1969. Reprinted by permission of John Wiley & Sons, Inc.


percentage humidity
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
5%
2%
adiabatic saturation curve
Temperature (°C)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
Humidity, H (kg water vapor/kg dry air)

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