$\frac{7.5}{10}$

UNIVERSITY OF JORDAN

CHEMICAL ENGINEERING DEPARTMENT

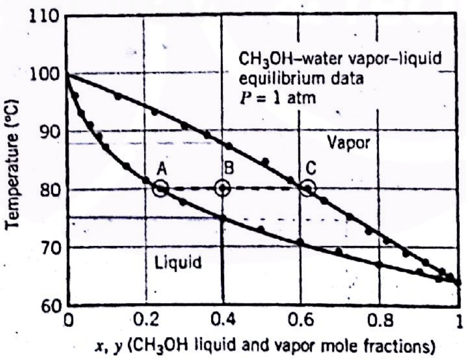
CHEMICAL ENGINEERING PRINCIPLES (2) -0905212

Name	[redacted]
University ID	[redacted]
Exam	First
Date	Monday, 24/3/2014
Time	30 minutes
Instructor	Eng. Shuruq Shawish

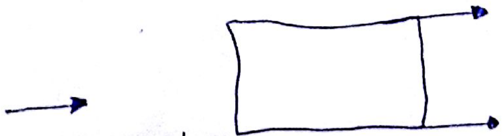
شعبة (1)

Question 1 (2 marks)

A Txy diagram for methanol-water mixtures at 1 atm absolute is show below, the feed to a vaporizer has a methanol mole fraction of $x_f = 0.4$, use the Txy diagram to estimate the minimum and maximum temperatures at which the given feed stream could be separated into vapor and liquid fractions at 1 atm.



2



0.4 mol CH_3OH/mol
0.6 mol W/mol

P = 1atm

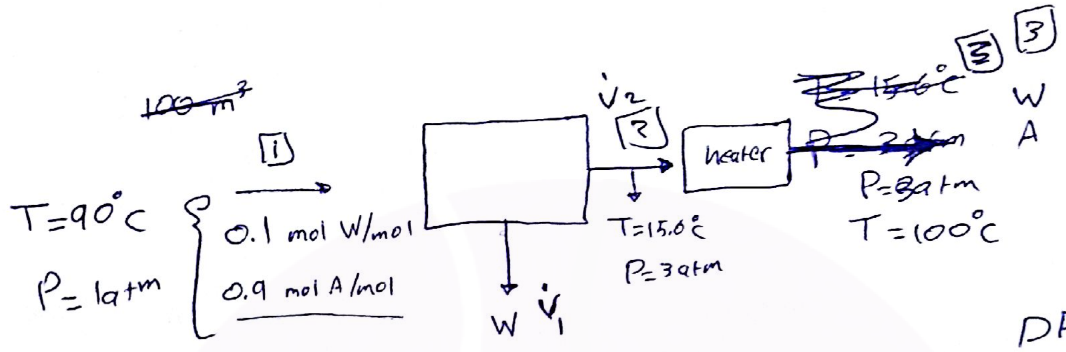
Min $\boxed{T = 75°C}$

Max = 88°C

Question 2 (8 marks)

Air at 90°C and 1.00 atm contains 10.0 mol% water. A continuous stream of this air enters a compressor-condenser, in which the temperature is lowered to 15.6°C and the pressure is raised to 3.00 atm. The air leaving the condenser is then heated isobarically to 100°C. Calculate the **fraction of water that is condensed from the air, the relative humidity of the air at 100°C, and the ratio m³ outlet air @ 100°C per m³ feed air @ 90°C.**

Antoine Equation Constants for water: A = 7.96681 B = 1668.21 C = 228.00



DF: 3 unknown
- 2 component
- P, T relation

0 ✳

* Basis of calculation:
* 100 m³/h feed :-

moles

~~Air balance~~
~~$\dot{V}_{1A} = \dot{V}_{1A}$~~
~~$(0.9)(100) = \dot{V}_{1A} = 90\ m^3/h$~~

at [2] $y_w = x\,P^*(15.6C)$ / ~~760 mmHg~~ 3atm | 760 mmHg / 1atm

$P^*(15.6°) = 7.96681 - \frac{1668.21}{228+15.6} =$

$\boxed{P = 13.14\ \text{mmHg}}$ 1

~~$y_w = 0.0058$~~
~~$y_A = 0.9994$~~

1

$y_w = 0.0058$
$y_A = 0.9994$

~~Water balance~~
~~$(0.1)(100)$~~

mole balance
mass //
not volume balance !!!

$\dot{V}_2 + y_A = (0.9)(100)$

$\dot{V}_2 = 90.05\ m^3/h$ moles 0.5

: Water balance

$0.1(100) = (90.05)(0.0058) + \dot{V}_1$ 0.5

$\dot{V}_1 =$ ~~[illegible]~~ m^3 moles

$9.48\ m^3/h$

[1] Fraction of water condensed $= \frac{9.48}{100 \times 0.1} = 0.984$ 0.5

⟹

~~[illegible]~~

اكمال

⟸

2

at $\boxed{3}$:-

relative hm = $\dfrac{P_{H_2O}}{P_{H_2O}(100)}$

$= \dfrac{P_{H_2O}}{758.6} \%$ $\; y_{H_2O} P$

$= \dfrac{\cancel{P_{H_2O}}(0.0058)(3\times760)}{758.6}$

$= 1.74\%$ 1

at $\boxed{2}$

$y_w = 0.1$

$y_A = 0.9$

$X_w = \dfrac{y_w P}{P^*(15.6)}$

$=$

$= \dfrac{\text{outlet air @ } 100^\circ C}{\text{feed air @ } 90^\circ C}$

$= \dfrac{89.995}{90} \alpha$

$= 0.9999 \alpha$ 1

UNIVERSITY OF JORDAN

CHEMICAL ENGINEERING DEPARTMENT

CHEMICAL ENGINEERING PRINCIPLES (2) -0905212

Name	[redacted]
Section	1
University ID	[redacted]
Exam	Mid Term
Date	Monday, 14/4/2014
Time	60 minutes
Instructor	Eng. Shuruq Shawish

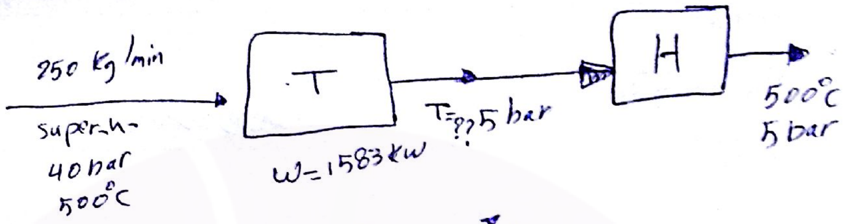
Problem	Full Mark	Mark
1	10	10
2	10	8.5
Total	20	18.5

10

Question 1 (10 marks)

Superheated steam at 40 bar absolute and 500°C flows at a rate of 250 kg/min to an adiabatic turbine, where it expands to 5 bar. The turbine delivers 1583 kW. From the turbine the steam flows to a heater, where it is reheated isobarically to its initial temperature. Neglecting kinetic and potential energy changes:

a. Write an energy balance on the turbine to determine the outlet steam temperature.
b. Write an energy balance on the heater and use it to determine the required heat input (kW) to the steam.



a

$\Delta\dot{H} + \cancel{\Delta\dot{E}_p} + \cancel{\Delta\dot{E}_k} = \cancel{\dot{Q}} - \dot{W}$

$\Delta\dot{H} = -\dot{W}$ 1

$\Delta\dot{H} = -1583 \text{ kW}$

$4.2\hat{H} - 14469 \overset{kW}{=} -1583 \text{ kW}$

$\hat{H} = 3068.1 \text{ kJ}$ 2

$\boxed{T = 300°C}$ 1

$\Delta\hat{H} = \hat{H}_{out} - 3445$ 1

$\Delta\dot{H} = \frac{250}{60}(\hat{H}_{out} - 3445)$

b

$\Delta\dot{H} = \dot{Q}$

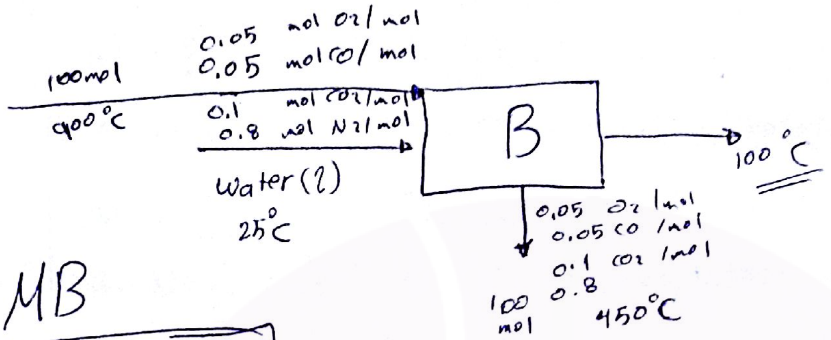
$(3484)\left(\frac{250}{60}\right) - \left(\frac{250}{60}\right)(3068.) = \dot{Q}$

$\boxed{\dot{Q} = 1733.3 \text{ kW}}$ 5

(8.5)

Question 2 (10 marks)

A hot gas stream containing 5 mol% CO, 10 mol% CO_2, 5 mol% O_2 and 80 mol% N_2 flows over the outside of the tubes of an adiabatic waste heat boiler. Liquid water at 25°C is fed to the boiler and flows inside the tubes of the boiler. How much saturated steam in (kg) at 100°C can be produced from the boiler feed water if 100 mol of the hot gas enters the boiler at 900°C and leaves at 450°C?



no ΔE_k
$\Delta \dot{E}_p$
no W
no Q

$\Delta \dot{H} = \phi$

* MB

$$\boxed{(n_w)_{in} = (n_w)_{out}}$$

(O_2, CO, CO_2, N_2) Ref (1) is (g, 1atm, 25°C)

Ref water (1) triple pt of water

	n_i mol	$\hat{H}_i$ kJ/mol	n_{out} mol	$\hat{H}_{out}$ kJ/mol
O_2	5	28.89	5	13.38
CO	5	27.49	5	12.82
CO_2	10	47.49	10	18.85
N_2	80	27.19	80	12.70
$H_2O(l)$	n	104.8 kJ/kg	~~n~~	—
$H_2O(g)$	~~—~~		n	2676 kJ/kg

(5)

why ??

$\hat{H}$ for O_2

$$\frac{500-400}{450-400} = \frac{15.03-11.72}{\hat{H} - 11.72}$$

$\hat{H} = 13.38$ kJ/mol

$\hat{H}$ for CO

$$\frac{500-400}{450-400} = \frac{14.38-11.25}{\hat{H} - 11.25}$$

$\hat{H} = 12.82$ kJ/mol

$\hat{H}$ for CO_2

$$\frac{500-400}{450-400} = \frac{21.34-16.35}{\hat{H} - 16.35}$$

$\hat{H} = 18.85$

$\hat{H}$ for N_2

$$\frac{500-400}{450-400} = \frac{14.24-11.15}{\hat{H} - 11.15}$$

$\hat{H} = 12.70$

just take the middle pt.

* EB :-

$\Delta \dot{H} = \dot{H}_{out} - \dot{H}_{in} = 0$ (0.5)

$(13.38)(5) + (12.82)(5) + (18.85)(10) + (12.7)(80) + (n)(2676)$

$= (5)(28.89) + (5)(27.49) + 10(47.49) + (80)(27.19) + n(104.8)$

$1335.5 + n(2676) = 2932 + n(104.8)$

$2571.2n = 1595.5$

(1) $n = 0.621$ mol these grams !! $\times\ 18 \frac{1}{mol}$

$$\boxed{m = 11.18 \times 10^{-3}\ kg}$$ X

3

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Table B.7 Properties of Superheated Steam[a]

P(bar) (T_{sat} °C)		Sat'd Water	Sat'd Steam	50	75	100	150	200	250	300	350
0.0	$\hat{H}$	—	—	2595	2642	2689	2784	2880	2978	3077	3177
(—)	$\hat{U}$	—	—	2446	2481	2517	2589	2662	2736	2812	2890
	$\hat{V}$	—	—	—	—	—	—	—	—	—	—
0.1	$\hat{H}$	191.8	2584.8	2593	2640	2688	2783	2880	2977	3077	3177
(45.8)	$\hat{U}$	191.8	2438.0	2444	2480	2516	2588	2661	2736	2812	2890
	$\hat{V}$	0.00101	14.7	14.8	16.0	17.2	19.5	21.8	24.2	26.5	28.7
0.5	$\hat{H}$	340.6	2646.0	209.3	313.9	2683	2780	2878	2979	3076	3177
(81.3)	$\hat{U}$	340.6	2484.0	209.2	313.9	2512	2586	2660	2735	2811	2889
	$\hat{V}$	0.00103	3.24	0.00101	0.00103	3.41	3.89	4.35	4.83	5.29	5.75
1.0	$\hat{H}$	417.5	2675.4	209.3	314.0	2676	2776	2875	2975	3074	3176
(99.6)	$\hat{U}$	417.5	2506.1	209.2	313.9	2507	2583	2658	2734	2811	2889
	$\hat{V}$	0.00104	1.69	0.00101	0.00103	1.69	1.94	2.17	2.40	2.64	2.87
5.0	$\hat{H}$	640.1	2747.5	209.7	314.3	419.4	632.2	2855	2961	3065	3168
(151.8)	$\hat{U}$	639.6	2560.2	209.2	313.8	418.8	631.6	2643	2724	2803	2883
	$\hat{V}$	0.00109	0.375	0.00101	0.00103	0.00104	0.00109	0.425	0.474	0.522	0.571
10	$\hat{H}$	762.6	2776.2	210.1	314.7	419.7	632.5	2827	2943	3052	3159
(179.9)	$\hat{U}$	761.5	2582	209.1	313.7	418.7	631.4	2621	2710	2794	2876
	$\hat{V}$	0.00113	0.194	0.00101	0.00103	0.00104	0.00109	0.206	0.233	0.258	0.282
20	$\hat{H}$	908.6	2797.2	211.0	315.5	420.5	633.1	852.6	2902	3025	3139
(212.4)	$\hat{U}$	906.2	2598.2	209.0	313.5	418.4	603.9	850.2	2679	2774	2862
	$\hat{V}$	0.00118	0.09950	0.00101	0.00102	0.00104	0.00109	0.00116	0.111	0.125	0.139
40	$\hat{H}$	1087.4	2800.3	212.7	317.1	422.0	634.3	853.4	1085.8	2962	3095
(250.3)	$\hat{U}$	1082.4	2601.3	208.6	313.0	417.8	630.0	848.8	1080.8	2727	2829
	$\hat{V}$	0.00125	0.04975	0.00101	0.00102	0.00104	0.00109	0.00115	0.00125	0.0588	0.0665
60	$\hat{H}$	1213.7	2785.0	214.4	318.7	423.5	635.6	854.2	1085.8	2885	3046
(275.6)	$\hat{U}$	1205.8	2590.4	208.3	312.6	417.3	629.1	847.3	1078.3	2668	2792
	$\hat{V}$	0.00132	0.0325	0.00101	0.00103	0.00104	0.00109	0.00115	0.00125	0.0361	0.0422
80	$\hat{H}$	1317.1	2759.9	216.1	320.3	425.0	636.8	855.1	1085.8	2787	2990
(295.0)	$\hat{U}$	1306.0	2571.7	208.1	312.3	416.7	628.2	845.9	1075.8	2593	2750
	$\hat{V}$	0.00139	0.0235	0.00101	0.00102	0.00104	0.00109	0.00115	0.00124	0.0243	0.0299
100	$\hat{H}$	1408.0	2727.7	217.8	322.9	426.5	638.1	855.9	1085.8	1343.4	2926
(311.0)	$\hat{U}$	1393.5	2547.3	207.8	311.7	416.1	627.3	844.4	1073.4	1329.4	2702
	$\hat{V}$	0.00145	0.0181	0.00101	0.00102	0.00104	0.00109	0.00115	0.00124	0.00140	0.0224
150	$\hat{H}$	1611.0	2615.0	222.1	326.0	430.3	641.3	858.1	1086.2	1338.2	2695
(342.1)	$\hat{U}$	1586.1	2459.9	207.0	310.7	414.7	625.0	841.0	1067.7	1317.6	2523
	$\hat{V}$	0.00166	0.0103	0.00101	0.00102	0.00104	0.00108	0.00114	0.00123	0.00138	0.0115
200	$\hat{H}$	1826.5	2418.4	226.4	330.0	434.0	644.5	860.4	1086.7	1334.3	1647.1
(365.7)	$\hat{U}$	1785.7	2300.8	206.3	309.7	413.2	622.9	837.7	1062.2	1307.1	1613.7
	$\hat{V}$	0.00204	0.005875	0.00100	0.00102	0.00103	0.00108	0.00114	0.00122	0.00136	0.00167
221.2(P_c)	$\hat{H}$	2108	2108	228.2	331.7	435.7	645.8	861.4	1087.0	1332.8	1635.5
(374.15)(T_c)	$\hat{U}$	2037.8	2037.8	206.0	309.2	412.8	622.0	836.3	1060.0	1302.9	1600.3
	$\hat{V}$	0.00317	0.00317	0.00100	0.00102	0.00103	0.00108	0.00114	0.00122	0.00135	0.00163
250	$\hat{H}$	—	—	230.7	334.0	437.8	647.7	862.8	1087.5	1331.1	1625.0
(—)	$\hat{U}$	—	—	205.7	308.7	412.1	620.8	834.4	1057.0	1297.5	1585.0
	$\hat{V}$	—	—	0.00100	0.00101	0.00103	0.00108	0.00113	0.00122	0.00135	0.00160
300	$\hat{H}$	—	—	235.0	338.1	441.6	650.9	865.2	1088.4	1328.7	1609.9
(—)	$\hat{U}$	—	—	205.0	307.7	410.8	618.7	831.3	1052.1	1288.7	1563.3
	$\hat{V}$	—	—	0.0009990	0.00101	0.00103	0.00107	0.00113	0.00121	0.00133	0.00155
500	$\hat{H}$	—	—	251.9	354.2	456.8	664.1	875.4	1093.6	1323.7	1576.3
(—)	$\hat{U}$	—	—	202.4	304.0	405.8	611.0	819.7	1034.3	1259.3	1504.1
	$\hat{V}$	—	—	0.0009911	0.00100	0.00102	0.00106	0.00111	0.00119	0.00129	0.00144
1000	$\hat{H}$	—	—	293.9	394.3	495.1	698.0	903.5	1113.0	1328.7	1550.5
(—)	$\hat{U}$	—	—	196.5	295.7	395.1	594.4	795.3	999.0	1207.1	1419.0
	$\hat{V}$	—	—	0.0009737	0.0009852	0.001000	0.00104	0.00108	0.00114	0.00122	0.00131

[a]Adapted from R. W. Haywood, *Thermodynamic Tables in SI (Metric) Units*, Cambridge University Press, London, 1968. Water is a liquid in the enclosed region between 50°C and 350°C. $\hat{H}$ = specific enthalpy (kJ/kg), $\hat{U}$ = specific internal energy (kJ/kg), $\hat{V}$ = specific volume (m^3/kg). *Note:* kJ/kg × 0.4303 = Btu/lb_m.

(continued)

Table B.7 (Continued)

P(bar) (T_{sat} °C)		400	450	500	550	600	650	700	750
0.0	$\hat{H}$	3280	3384	3497	3597	3706	3816	3929	4043
(—)	$\hat{U}$	2969	3050	3132	3217	3303	3390	3480	3591
	$\hat{V}$	—	—	—	—	—	—	—	—
0.1	$\hat{H}$	3280	3384	3489	3596	3706	3816	3929	4043
(45.8)	$\hat{U}$	2969	3050	3132	3217	3303	3390	3480	3571
	$\hat{V}$	21.1	33.3	35.7	38.0	40.3	42.6	44.8	47.2
0.5	$\hat{H}$	3279	3383	3489	3596	3705	3816	3929	4043
(81.3)	$\hat{U}$	2969	3049	3132	3216	3302	3390	3480	3571
	$\hat{V}$	6.21	6.67	7.14	7.58	8.06	8.55	9.01	9.43
1.0	$\hat{H}$	3278	3382	3488	3596	3705	3816	3928	4042
(99.6)	$\hat{U}$	2968	3049	3132	3216	3302	3390	3479	3570
	$\hat{V}$	3.11	3.33	3.57	3.80	4.03	4.26	4.48	4.72
5.0	$\hat{H}$	3272	3379	3484	3592	3702	3813	3926	4040
(151.8)	$\hat{U}$	2964	3045	3128	3213	3300	3388	3477	3569
	$\hat{V}$	0.617	0.664	0.711	0.758	0.804	0.850	0.897	0.943
10	$\hat{H}$	3264	3371	3478	3587	3697	3809	3923	4038
(179.9)	$\hat{U}$	2958	3041	3124	3210	3296	3385	3475	3567
	$\hat{V}$	0.307	0.330	0.353	0.377	0.402	0.424	0.448	0.472
20	$\hat{H}$	3249	3358	3467	3578	3689	3802	3916	4032
(212.4)	$\hat{U}$	2946	3031	3115	3202	3290	3379	3470	3562
	$\hat{V}$	0.151	0.163	0.175	0.188	0.200	.0211	0.223	0.235
40	$\hat{H}$	3216	3331	3445	3559	3673	3788	3904	4021
(250.3)	$\hat{U}$	2922	3011	3100	3188	3278	3368	3460	3554
	$\hat{V}$	0.0734	0.0799	0.0864	0.0926	0.0987	0.105	0.111	0.117
60	$\hat{H}$	3180	3303	3422	3539	3657	3774	3892	4011
(275.6)	$\hat{U}$	2896	2991	3083	3174	3265	3357	3451	3545
	$\hat{V}$	0.0474	0.0521	0.0566	0.0609	0.0652	0.0693	0.0735	0.0776
80	$\hat{H}$	3142	3274	3399	3520	3640	3759	3879	4000
(295.0)	$\hat{U}$	2867	2969	3065	3159	3252	3346	3441	3537
	$\hat{V}$	0.0344	0.0382	0.0417	0.0450	0.0483	0.0515	0.0547	0.0578
100	$\hat{H}$	3100	3244	3375	3500	3623	3745	3867	3989
(311.0)	$\hat{U}$	2836	2946	3047	3144	3240	3335	3431	3528
	$\hat{V}$	0.0264	0.0298	0.0328	0.0356	0.0383	0.0410	0.0435	0.0461
150	$\hat{H}$	2975	3160	3311	3448	3580	3708	3835	3962
(342.1)	$\hat{U}$	2744	2883	2999	3105	3207	3307	3407	3507
	$\hat{V}$	0.0157	0.0185	0.0208	0.0229	0.0249	0.0267	0.0286	0.0304
200	$\hat{H}$	2820	3064	3241	3394	3536	3671	3804	3935
(365.7)	$\hat{U}$	2622	2810	2946	3063	3172	3278	3382	3485
	$\hat{V}$	0.009950	0.0127	0.0148	0.0166	0.0182	0.197	0.211	0.0225
221.2(P_c)	$\hat{H}$	2733	3020	3210	3370	3516	3655	3790	3923
(374.15)(T_c)	$\hat{U}$	2553	2776	2922	3045	3157	3265	3371	3476
	$\hat{V}$	0.008157	0.0110	0.0120	0.0147	0.0162	0.0176	0.0190	0.0202
250	$\hat{H}$	2582	2954	3166	3337	3490	3633	3772	3908
(—)	$\hat{U}$	2432	2725	2888	3019	3137	3248	3356	3463
	$\hat{V}$	0.006013	0.009174	0.0111	0.0127	0.0141	0.0143	0.0166	0.0178
300	$\hat{H}$	2162	2826	3085	3277	3443	3595	3740	3880
(—)	$\hat{U}$	2077	2623	2825	2972	3100	3218	3330	3441
	$\hat{V}$	0.002830	0.006734	0.008680	0.0102	0.0114	0.0126	0.0136	0.0147
500	$\hat{H}$	1878	2293	2723	3021	3248	3439	3610	3771
(—)	$\hat{U}$	1791	2169	2529	2765	2946	3091	3224	3350
	$\hat{V}$	0.001726	0.002491	0.003882	0.005112	0.006112	0.007000	0.007722	0.008418
1000	$\hat{H}$	1798	2051	2316	2594	2857	3105	3324	3526
(—)	$\hat{U}$	1653	1888	2127	2369	2591	2795	2971	3131
	$\hat{V}$	0.001446	0.001628	0.001893	0.002246	0.002668	0.003106	0.003536	0.003953

Table B.8 Specific Enthalpies of Selected Gases: SI Units

$\hat{H}$(kJ/mol)
Reference state: Gas, P_{ref} = 1 atm, T_{ref} = 25°C

T	Air	O_2	N_2	H_2	CO	CO_2	H_2O
0	−0.72	−0.73	−0.73	−0.72	−0.73	−0.92	−0.84
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	2.19	2.24	2.19	2.16	2.19	2.90	2.54
200	5.15	5.31	5.13	5.06	5.16	7.08	6.01
300	8.17	8.47	8.12	7.96	8.17	11.58	9.57
400	11.24	11.72	11.15	10.89	11.25	16.35	13.23
500	14.37	15.03	14.24	13.83	14.38	21.34	17.01
600	17.55	18.41	17.39	16.81	17.57	26.53	20.91
700	20.80	21.86	20.59	19.81	20.82	31.88	24.92
800	24.10	25.35	23.86	22.85	24.13	37.36	29.05
900	27.46	28.89	27.19	25.93	27.49	42.94	33.32
1000	30.86	32.47	30.56	29.04	30.91	48.60	37.69
1100	34.31	36.07	33.99	32.19	34.37	54.33	42.18
1200	37.81	39.70	37.46	35.39	37.87	60.14	46.78
1300	41.34	43.38	40.97	38.62	41.40	65.98	51.47
1400	44.89	47.07	44.51	41.90	44.95	71.89	56.25
1500	48.45	50.77	48.06	45.22	48.51	77.84	61.09

Table B.9 Specific Enthalpies of Selected Gases: American Engineering Units

$\hat{H}$(Btu/lb-mole)
Reference state: Gas, P_{ref} = 1 atm, T_{ref} = 77°F

T	Air	O_2	N_2	H_2	CO	CO_2	H_2O
32	−312	−315	−312	−310	−312	−394	−361
77	0	0	0	0	0	0	0
100	160	162	160	159	160	206	185
200	858	875	857	848	859	1132	996
300	1563	1602	1558	1539	1564	2108	1818
400	2275	2342	2265	2231	2276	3129	2652
500	2993	3094	2976	2925	2994	4192	3499
600	3719	3858	3694	3621	3720	5293	4359
700	4451	4633	4418	4319	4454	6429	5233
800	5192	5418	5150	5021	5195	7599	6122
900	5940	6212	5889	5725	5945	8790	7025
1000	6695	7015	6635	6433	6702	10015	7944
1100	7459	7826	7399	7145	7467	11263	8880
1200	8230	8645	8151	7861	8239	12533	9831
1300	9010	9471	8922	8581	9021	13820	10799
1400	9797	10304	9699	9306	9809	15122	11783
1500	10590	11142	10485	10035	10606	16436	12783
1600	11392	11988	11278	10769	11409	17773	13798
1700	12200	12836	12080	11509	12220	19119	14831
1800	13016	13691	12888	12254	13036	20469	15877
1900	13837	14551	13702	13003	13858	21840	16941
2000	14663	15415	14524	13759	14688	23211	18019

Table B.5 Properties of Saturated Steam: Temperature Table[a]

		$\hat{V}$(m³/kg)		$\hat{U}$(kJ/kg)		$\hat{H}$(kJ/kg)		
T(°C)	P(bar)	Water	Steam	Water	Steam	Water	Evaporation	Steam
0.01	0.00611	0.001000	206.2	zero	2375.6	+0.0	2501.6	2501.6
2	0.00705	0.001000	179.9	8.4	2378.3	8.4	2496.8	2505.2
4	0.00813	0.001000	157.3	16.8	2381.1	16.8	2492.1	2508.9
6	0.00935	0.001000	137.8	25.2	2383.8	25.2	2487.4	2512.6
8	0.01072	0.001000	121.0	33.6	2386.6	33.6	2482.6	2516.2
10	0.01227	0.001000	106.4	42.0	2389.3	42.0	2477.9	2519.9
12	0.01401	0.001000	93.8	50.4	2392.1	50.4	2473.2	2523.6
14	0.01597	0.001001	82.9	58.8	2394.8	58.8	2468.5	2527.2
16	0.01817	0.001001	73.4	67.1	2397.6	67.1	2463.8	2530.9
18	0.02062	0.001001	65.1	75.5	2400.3	75.5	2459.0	2534.5
20	0.0234	0.001002	57.8	83.9	2403.0	83.9	2454.3	2538.2
22	0.0264	0.001002	51.5	92.2	2405.8	92.2	2449.6	2541.8
24	0.0298	0.001003	45.9	100.6	2408.5	100.6	2444.9	2545.5
25	0.0317	0.001003	43.4	104.8	2409.9	104.8	2442.5	2547.3
26	0.0336	0.001003	41.0	108.9	2411.2	108.9	2440.2	2549.1
28	0.0378	0.001004	36.7	117.3	2414.0	117.3	2435.4	2552.7
30	0.0424	0.001004	32.9	125.7	2416.7	125.7	2430.7	2556.4
32	0.0475	0.001005	29.6	134.0	2419.4	134.0	2425.9	2560.0
34	0.0532	0.001006	26.6	142.4	2422.1	142.4	2421.2	2563.6
36	0.0594	0.001006	24.0	150.7	2424.8	150.7	2416.4	2567.2
38	0.0662	0.001007	21.6	159.1	2427.5	159.1	2411.7	2570.8
40	0.0738	0.001008	19.55	167.4	2430.2	167.5	2406.9	2574.4
42	0.0820	0.001009	17.69	175.8	2432.9	175.8	2402.1	2577.9
44	0.0910	0.001009	16.04	184.2	2435.6	184.2	2397.3	2581.5
46	0.1009	0.001010	14.56	192.5	2438.3	192.5	2392.5	2585.1
48	0.1116	0.001011	13.23	200.9	2440.9	200.9	2387.7	2588.6
50	0.1234	0.001012	12.05	209.2	2443.6	209.3	2382.9	2592.2
52	0.1361	0.001013	10.98	217.7	2446	217.7	2377	2595
54	0.1500	0.001014	10.02	226.0	2449	226.0	2373	2599
56	0.1651	0.001015	9.158	234.4	2451	234.4	2368	2602
58	0.1815	0.001016	8.380	242.8	2454	242.8	2363	2606
60	0.1992	0.001017	7.678	251.1	2456	251.1	2358	2609
62	0.2184	0.001018	7.043	259.5	2459	259.5	2353	2613
64	0.2391	0.001019	6.468	267.9	2461	267.9	2348	2616
66	0.2615	0.001020	5.947	276.2	2464	276.2	2343	2619
68	0.2856	0.001022	5.475	284.6	2467	284.6	2338	2623
70	0.3117	0.001023	5.045	293.0	2469	293.0	2333	2626
72	0.3396	0.001024	4.655	301.4	2472	301.4	2329	2630
74	0.3696	0.001025	4.299	309.8	2474	309.8	2323	2633
76	0.4019	0.001026	3.975	318.2	2476	318.2	2318	2636
78	0.4365	0.001028	3.679	326.4	2479	326.4	2313	2639
80	0.4736	0.001029	3.408	334.8	2482	334.9	2308	2643
82	0.5133	0.001030	3.161	343.2	2484	343.3	2303	2646
84	0.5558	0.001032	2.934	351.6	2487	351.7	2298	2650
86	0.6011	0.001033	2.727	360.0	2489	360.1	2293	2653
88	0.6495	0.001034	2.536	368.4	2491	368.5	2288	2656
90	0.7011	0.001036	2.361	376.9	2493	377.0	2282	2659
92	0.7560	0.001037	2.200	385.3	2496	385.4	2277	2662
94	0.8145	0.001039	2.052	393.7	2499	393.8	2272	2666
96	0.8767	0.001040	1.915	402.1	2501	402.2	2267	2669
98	0.9429	0.001042	1.789	410.6	2504	410.7	2262	2673
100	1.0131	0.001044	1.673	419.0	2507	419.1	2257	2676
102	1.0876	0.001045	1.566	427.1	2509	427.5	2251	2679

17/20

UNIVERSITY OF JORDAN

CHEMICAL ENGINEERING DEPARTMENT

CHEMICAL ENGINEERING PRINCIPLES (2) -0905212

Name	[redacted]	**Exam**	Second Exam
Section	1	**Date**	Wednesday, 30/4/2014
University ID	[redacted]	**Instructor**	Eng. Shuruq Shawish

Question 1 (7 marks)

7

Use the psychrometric chart to estimate:

1. The absolute humidity, wet-bulb temperature, humid volume, dew point temperature and specific enthalpy of humid air at $\boxed{43°C}$ and $\boxed{30\%}$ relative humidity.
2. The mass of water in 100 m^3 of air at these conditions.

1.

absolute humidity: 0.0166 Kg H_2O / Kg DA

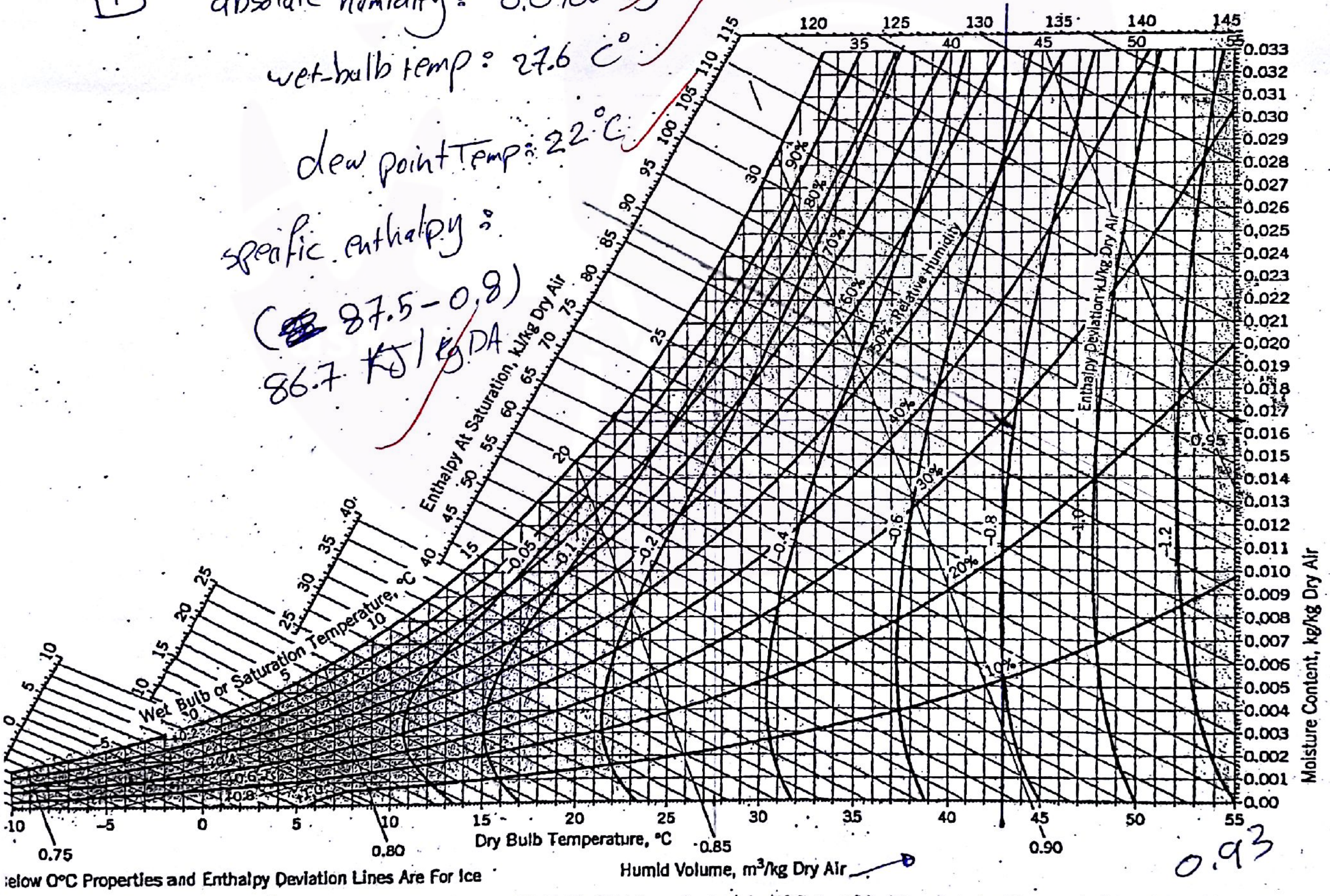
wet-bulb temp: 27.6 C°

dew point Temp: 22 °C

specific enthalpy:

(87.5 − 0.8)

86.7 KJ / Kg DA



0.93

re 8.4-1 Psychrometric chart—SI units. Reference states: H_2O (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier poration.)

2.

$$100\ m^3 \left| \frac{Kg\ DA}{0.93\ m^3} \right| \frac{0.0166\ Kg\ H_2O}{Kg\ DA} \Big| = 1.785\ Kg\ H_2O$$

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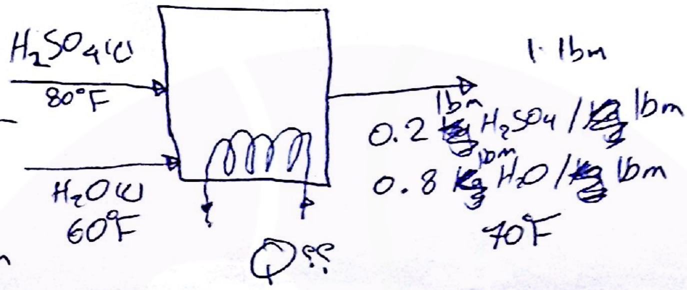
Question 2 (13 marks)

In a battery plant, pure $H_2SO_{4(l)}$ at 80°F is mixed with pure $H_2O_{(l)}$ at 60°F to make a 20 wt% solution at 70°F. How much heat was removed per 1 lb_m of final solution?

Component	C_p (Btu/lb_m.°F)
$H_2O_{(l)}$	1
$H_2SO_{4(l)}$	0.3352
$H_2SO_{4(aq)}$ (20%)	0.8307

r (lb-mol H_2O/lb-mol H_2SO_4)	$\Delta\hat{H}_m$ (Btu/lb-mol H_2SO_4) at $\boxed{77°F}$
5	-2499.455
10	-28867
25	-31137.036



$\Delta\dot{H} = \dot{Q}$ 1

From the Mass Balance :-

Mass of H_2SO_4 = 0.2 lbm

" " H_2O = 0.8 lbm

H_2SO_4 (l, 80°F) $\quad$ H_2O (l, 60°F)

Ref. State ? 2

$\downarrow \Delta\hat{H}_1$ $\quad$ $\downarrow \Delta\hat{H}_2$

$\int_{80}^{77} (C_p)_{H_2SO_4(l)}\, dT$ $\quad$ $\int_{60}^{77} (C_p)_{H_2O(l)}\, dT$

$= 0.3352(77-80)$ $\quad$ $\Delta\hat{H} = \int_{60}^{77} 1\, dT = (1)(77-60)$

1 $\Delta\hat{H}_1 = -1.0056$ (Btu/lbm) $\quad$ $\Delta\hat{H}_2 = 17$ (Btu/lbm) 1

$\downarrow \Delta\hat{H}_m$ From the table

H_2SO_4 (aq) at 77°C

$\downarrow \Delta\hat{H}_4$

$\Delta\hat{H}_4 = \int_{77}^{70} (C_p)_{H_2SO_4(aq)}\, dT$

$= (0.8307)(70-77)$ 1

$\Delta\hat{H}_4 = -5.8149$ Btu/lbm

To find r :-

$r = \dfrac{\left(\frac{0.8}{18}\right)}{\left(\frac{0.2}{98}\right)}$ 1 1 $= 22$ 1

$\dfrac{25-10}{-31137.036+28867} = \dfrac{22-10}{\Delta\hat{H}+28867}$ 1

$\Delta\hat{H}_m = -30683.029$ Btu/lb-mol H_2SO_4

$$\dot{Q} = \Delta\dot{H} = \left[(-5.8149)(1\,lbm) + (-30683.029)\left(\frac{0.2}{98}\right)\right]$$

$$- \left[(-1.0056)(0.2) + (17)(0.8)\right]$$

2

$$\dot{Q} = -81.83\,Btu$$