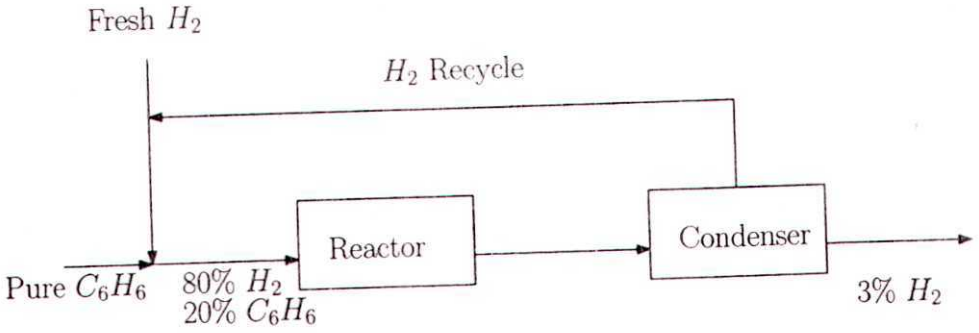
Instructions: Answer all questions. Use a single answer book for both the parts. All questions of a part must be answered together. Missing data should be suitably assumed. All assumptions must be stated clearly and explicitly. If there is any correction to the question, that will be announced in due time. No question/clarification will be entertained during the examination. **Please write your name and roll number on all charts/tables immediately after you receive them. All charts/tables must be *attached* to the main answer book securely and submitted along with the answer script.**

Part A

1. (8 marks) Benzene is converted to cyclohexane (C_6H_{12}) by reaction with H_2 in a recycle reactor as shown below:



The plant produces 100 lb-moles/hr of cyclohexane. Ninety nine percent of benzene fed to the *process* reacts to form cyclohexane. The composition of the stream entering the reactor is 80 mol% H_2 and 20 mol % C_6H_6 and the product stream contains 3 mole % H_2. Calculate:

   (a) The composition of the product stream
   (b) The feed rates of C_6H_6 and H_2
   (c) The recycle rates of H_2

2. (4 marks) A gas is flowing at 100,000 scfh (standard cubic feet/hr). What is the actual volumetric gas flow rate if the pressure is 50 atms and the temperature is 600 °R? The critical temperature is 40 °F and the critical pressure is 14.3 atms. How much error is introduced if this gas is treated as ideal gas under these conditions? (Generalized compressibility factor chart is available at the end of this question paper)

3. (5 marks) 1 lb of saturated air at 1 atms, 75 °F is taken in a piston-cylinder assembly, then it is compressed to 4 atms isothermally. If any water is condensed during the process, ALL of it is removed. Then the air is expanded back to 1 atms. What is the dew point temperature of this air? Obtain the answer by using steam table available at the end of this question paper)

4. (8 marks) A liquid mixture contains 50% Benzene and 50% toluene by MASS.

   (a) Calculate the total pressure and mol fractions of each component in the vapor (containing B + T only) in equilibrium with the given liquid mixture at 60 °C. The Antoine's equation is given by:

$$\ln(p^*) = A - \frac{B}{C+T}$$

where p^* is in mm Hg and T in K. The constants are given by:

	A	B	C
Benzene	15.9008	2788.51	-52.360
Toluene	16.0137	3096.52	-53.67

(b) Calculate the bubble point temperature of the liquid mixture at P_{total}=0.715 atms.

Part B

5. (4 marks) Atmosphereic air in a desert has a dry bulb temperature of 47 °C and wet bulb temperature of 29 °C. Locate the point on the Psychrometric Chart. What are the Specific Humidity and Humid Volume of the air under these conditions? At night what must be the temperature for dew to form? (Show it on the Psychrometric Chart) (1+2+1)

6. (5 marks) 500 Kg/hr of air enters a dryer. The initial moisture content of the feed air is 0.015 and dry bulb temperature is 110 °C. The dryer is operating adiabatically. Air leaves the dryer at relative humidity of 90%. Mark the process on the Psychrometric chart. What is the outlet absolute humidity of air? How much water can be removed by this drying process per hour? What is the change in Humid Volume and Humid Heat of air? (1+1+1+1+1)

7. (3 marks) Calculate the heat of formation of CO. Given that Standard heat of Formation of CO_2 is −393.51 KJ/gmol of CO_2 and Standard Heat of Reaction of Oxidation of CO is −282.99 KJ/gmol of CO.

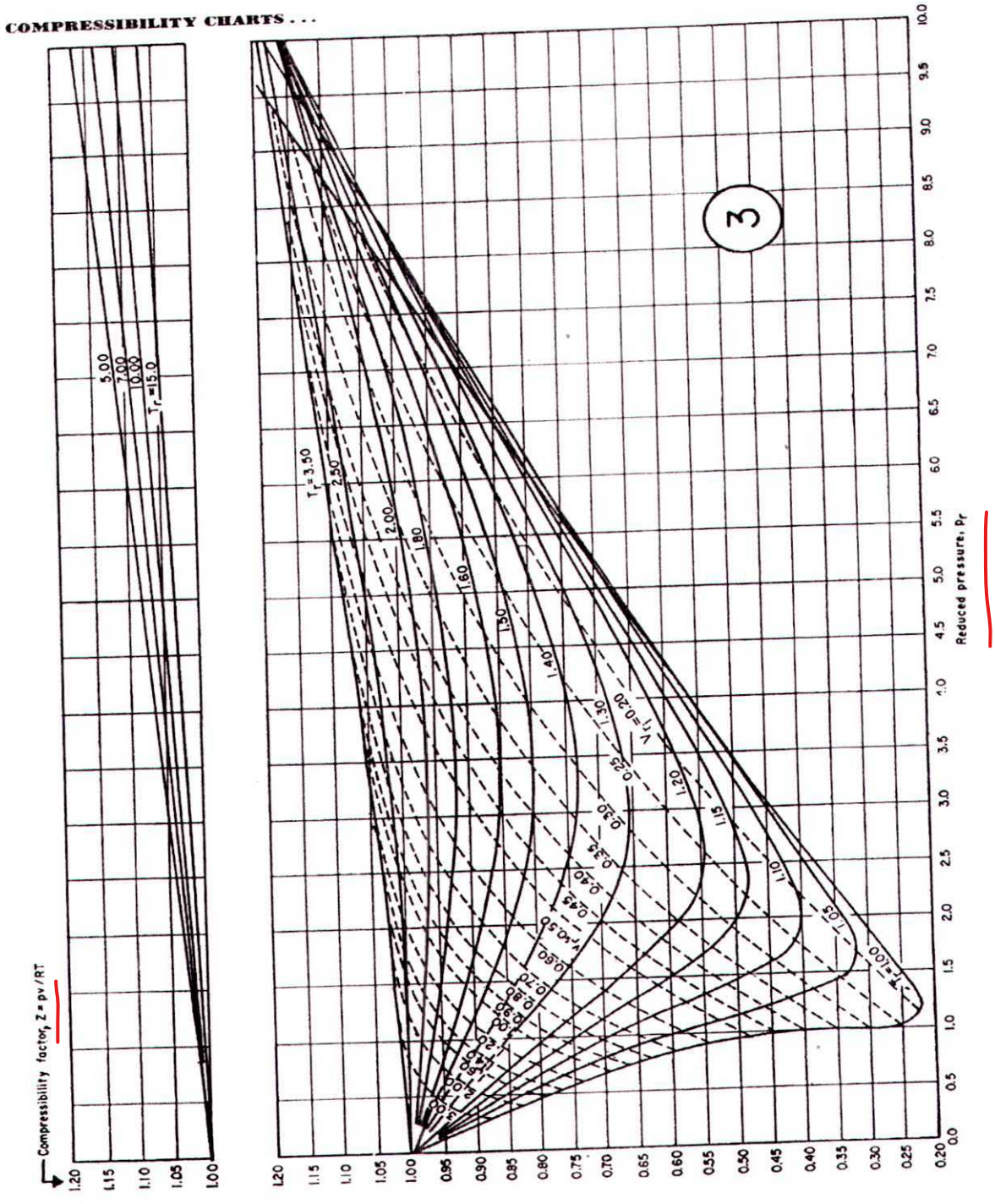
8. (7 marks) Given $\Delta H^o_{F,NaOH,aq.} = -112.23$ KCal/gmol, $\Delta H^o_{F,HCl,aq.} = -40.02$ KCal/gmol, $\Delta H^o_{F,NaCl,aq.} = -97.31$ KCal/gmol and $\Delta H^o_{F,Water} = -68.32$ KCal/gmol. What is the **heat of Neutralization** when a dilute solution of Nitric Acid is Neutralized with a dilute solution of KOH? (Feel free to assume any missing data). Based on the above calculation, further calculate the combined heat of formation of H^+ and OH^- in aqueous state. (5+2)

9. (3 marks) The vapor pressure of Ethyelene can be calculated from the following formulae:

$$P^*(mmHg) = 6.74756 - \frac{5850}{2550 - T}$$

Find out the value of Latent Heat of Vaporization (ΔH_v) of Ethylene in the temperature range 25 °C to 55 °C.

10. (3 marks) (a) Why a gas can never be liquefied by applying pressure above its critical temperature?
    (b) Can Δ°F (Br) = 111.888 KJ/mol be a correct statement? Justify!
    (c) What is Troutons Rule?


COMPRESSIBILITY CHARTS . . .
3
Compressibility factor, Z = pv/RT
Reduced pressure, Pr
T_r = 5.00
7.00
10.00
15.0
3.50
2.50
2.00
1.80
1.60
1.30
1.40
1.20
1.15
1.10
1.05
1.00
V_r' = 0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.60
0.70
0.80
0.90
1.00
1.05
1.10
1.15
1.20
1.30

Saturated water—Temperature table

		Specific volume, m^3/kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg · K		
Temp., T °C	Sat. press., P_{sat} kPa	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
0.01	0.6117	0.001000	206.00	0.000	2374.9	2374.9	0.001	2500.9	2500.9	0.0000	9.1556	9.1556
5	0.8725	0.001000	147.03	21.019	2360.8	2381.8	21.020	2489.1	2510.1	0.0763	8.9487	9.0249
10	1.2281	0.001000	106.32	42.020	2346.6	2388.7	42.022	2477.2	2519.2	0.1511	8.7488	8.8999
15	1.7057	0.001001	77.885	62.980	2332.5	2395.5	62.982	2465.4	2528.3	0.2245	8.5559	8.7803
20	2.3392	0.001002	57.762	83.913	2318.4	2402.3	83.915	2453.5	2537.4	0.2965	8.3696	8.6661
25	3.1698	0.001003	43.340	104.83	2304.3	2409.1	104.83	2441.7	2546.5	0.3672	8.1895	8.5567
30	4.2469	0.001004	32.879	125.73	2290.2	2415.9	125.74	2429.8	2555.6	0.4368	8.0152	8.4520
35	5.6291	0.001006	25.205	146.63	2276.0	2422.7	146.64	2417.9	2564.6	0.5051	7.8466	8.3517
40	7.3851	0.001008	19.515	167.53	2261.9	2429.4	167.53	2406.0	2573.5	0.5724	7.6832	8.2556
45	9.5953	0.001010	15.251	188.43	2247.7	2436.1	188.44	2394.0	2582.4	0.6386	7.5247	8.1633
50	12.352	0.001012	12.026	209.33	2233.4	2442.7	209.34	2382.0	2591.3	0.7038	7.3710	8.0748
55	15.763	0.001015	9.5639	230.24	2219.1	2449.3	230.26	2369.8	2600.1	0.7680	7.2218	7.9898
60	19.947	0.001017	7.6670	251.16	2204.7	2455.9	251.18	2357.7	2608.8	0.8313	7.0769	7.9082
65	25.043	0.001020	6.1935	272.09	2190.3	2462.4	272.12	2345.4	2617.5	0.8937	6.9360	7.8296
70	31.202	0.001023	5.0396	293.04	2175.8	2468.9	293.07	2333.0	2626.1	0.9551	6.7989	7.7540
75	38.597	0.001026	4.1291	313.99	2161.3	2475.3	314.03	2320.6	2634.6	1.0158	6.6655	7.6812
80	47.416	0.001029	3.4053	334.97	2146.6	2481.6	335.02	2308.0	2643.0	1.0756	6.5355	7.6111
85	57.868	0.001032	2.8261	355.96	2131.9	2487.8	356.02	2295.3	2651.4	1.1346	6.4089	7.5435
90	70.183	0.001036	2.3593	376.97	2117.0	2494.0	377.04	2282.5	2659.6	1.1929	6.2853	7.4782
95	84.609	0.001040	1.9808	398.00	2102.0	2500.1	398.09	2269.6	2667.6	1.2504	6.1647	7.4151
100	101.42	0.001043	1.6720	419.06	2087.0	2506.0	419.17	2256.4	2675.6	1.3072	6.0470	7.3542
105	120.90	0.001047	1.4186	440.15	2071.8	2511.9	440.28	2243.1	2683.4	1.3634	5.9319	7.2952
110	143.38	0.001052	1.2094	461.27	2056.4	2517.7	461.42	2229.7	2691.1	1.4188	5.8193	7.2382
115	169.18	0.001056	1.0360	482.42	2040.9	2523.3	482.59	2216.0	2698.6	1.4737	5.7092	7.1829
120	198.67	0.001060	0.89133	503.60	2025.3	2528.9	503.81	2202.1	2706.0	1.5279	5.6013	7.1292
125	232.23	0.001065	0.77012	524.83	2009.5	2534.3	525.07	2188.1	2713.1	1.5816	5.4956	7.0771
130	270.28	0.001070	0.66808	546.10	1993.4	2539.5	546.38	2173.7	2720.1	1.6346	5.3919	7.0265
135	313.22	0.001075	0.58179	567.41	1977.3	2544.7	567.75	2159.1	2726.9	1.6872	5.2901	6.9773
140	361.53	0.001080	0.50850	588.77	1960.9	2549.6	589.16	2144.3	2733.5	1.7392	5.1901	6.9294
145	415.68	0.001085	0.44600	610.19	1944.2	2554.4	610.64	2129.2	2739.8	1.7908	5.0919	6.8827
150	476.16	0.001091	0.39248	631.66	1927.4	2559.1	632.18	2113.8	2745.9	1.8418	4.9953	6.8371
155	543.49	0.001096	0.34648	653.19	1910.3	2563.5	653.79	2098.0	2751.8	1.8924	4.9002	6.7927
160	618.23	0.001102	0.30680	674.79	1893.0	2567.8	675.47	2082.0	2757.5	1.9426	4.8066	6.7492
165	700.93	0.001108	0.27244	696.46	1875.4	2571.9	697.24	2065.6	2762.8	1.9923	4.7143	6.7067
170	792.18	0.001114	0.24260	718.20	1857.5	2575.7	719.08	2048.8	2767.9	2.0417	4.6233	6.6650
175	892.60	0.001121	0.21659	740.02	1839.4	2579.4	741.02	2031.7	2772.7	2.0906	4.5335	6.6242
180	1002.8	0.001127	0.19384	761.92	1820.9	2582.8	763.05	2014.2	2777.2	2.1392	4.4448	6.5841
185	1123.5	0.001134	0.17390	783.91	1802.1	2586.0	785.19	1996.2	2781.4	2.1875	4.3572	6.5447
190	1255.2	0.001141	0.15636	806.00	1783.0	2589.0	807.43	1977.9	2785.3	2.2355	4.2705	6.5059
195	1398.8	0.001149	0.14089	828.18	1763.6	2591.7	829.78	1959.0	2788.8	2.2831	4.1847	6.4678
200	1554.9	0.001157	0.12721	850.46	1743.7	2594.2	852.26	1939.8	2792.0	2.3305	4.0997	6.4302

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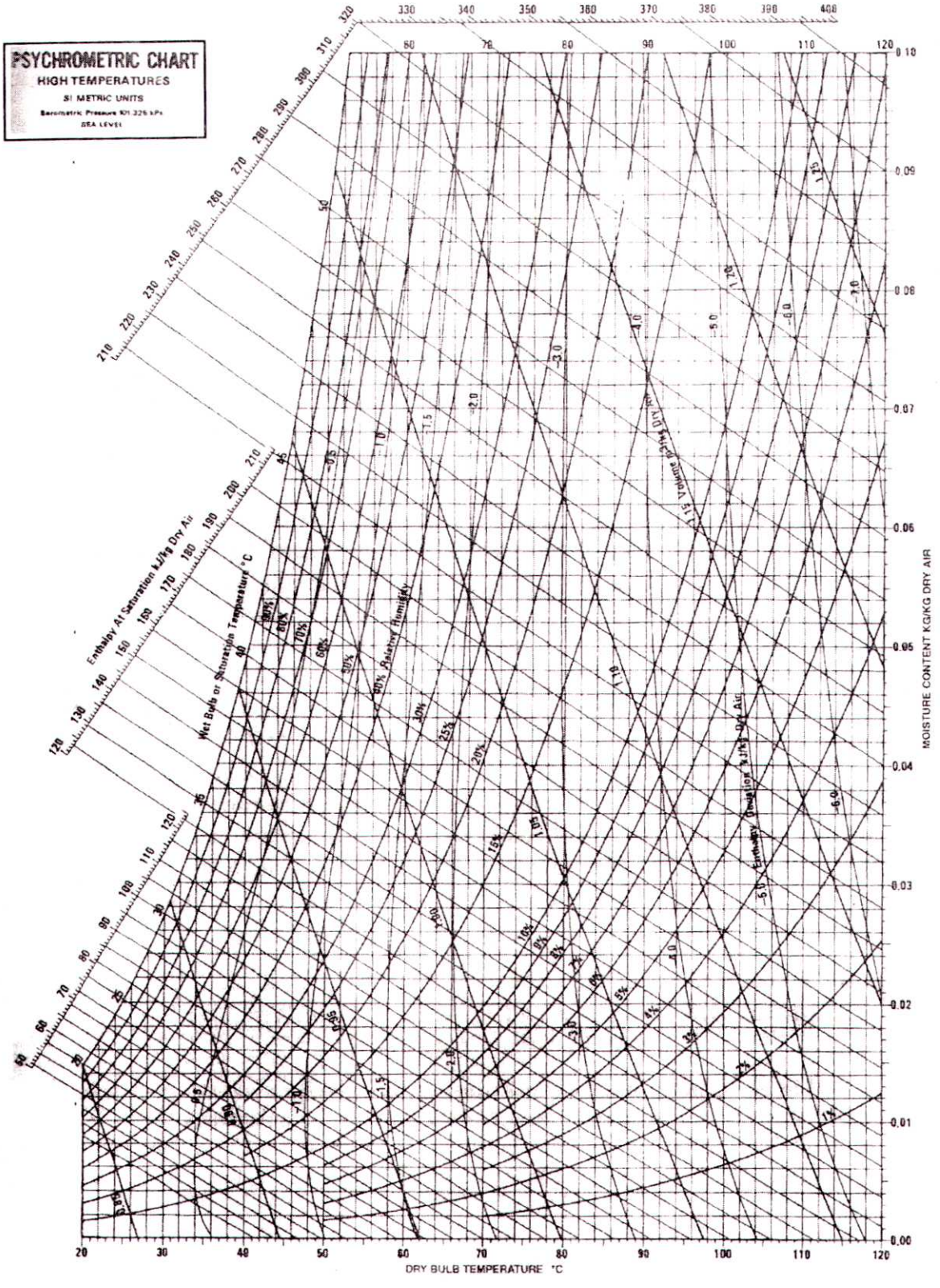

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