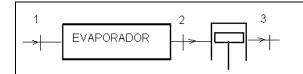
## Termodinâmica (Prova Substitutiva de 2012-1) (Prof. Frederico W. Tavares)

1)(40 Ptos) A figura a seguir mostra o processo de produção da mistura gasosa de A e B de composição equimolar. A corrente de entrada contém 30% (em base molar) de vapor a 1 atm. No processo, 500 cm³/min da mistura de A e B (composição equimolar) são produzidos a 20 atm e temperatura T<sub>3</sub>. Calcule a temperatura da corrente 2 e estime as taxas de calor e trabalho envolvidas no processo.

i- Fase gasosa: Gás Ideal

ii- 
$$C_{P,A}(T, 20atm) = R[4+0, 02T(K)]$$
 e  $C_{P,B}(T, 20atm) = R[6+0, 02T(K)]$   
 $P_A^{SAT}(bar) = 30 \exp[3-(1500/T(K))]$  e  $P_B^{SAT}(bar) = 35 \exp[2-(900/T(K))]$ 



Dados:

Corrente-1: 30% (em mols) de vapor a 1 atm

**Corrente-2**: vapor saturação **Corrente-3**: P=20 atm

2) (30Ptos) A reação n A(g) + 2n B(g) = 2n C(s) + n D(g) ocorre em um sistema gasoso fechado ideal, no qual a temperatura e a pressão são mantidas constantes e iguais a 400 K e 5 bar, respectivamente. A constante de equilíbrio da reação para n=1, calculada a partir da energia livre de Gibbs padrão de reação na temperatura do sistema, na pressão de 1 bar e no estado de gás ideal para os componentes A, B e D e estado de sólido puro para C é igual a 3. No instante inicial, há 1 gmol de A, 2 gmols de B e 5 gmols de inerte. Determine os números de mols dos compostos no equilíbrio para a reação com n=2.

3) (30Ptos) Duas correntes de água, corrente 1 (150 Kg/min de líquido a 50kPa e 45,8°C) e corrente 2 (x Kg/min nas condições de 50kPa e 500°C), são misturadas em um trocador de calor de contato direto, produzindo uma corrente 3, que deve ter 5%(em base mássica) de líquido. A corrente 3 passa em um compressor (com eficiência de 80%) e sai a 100kPa (corrente 4). Encontre as propriedades termodinâmicas (T, P, H e S) das correntes 1, 2, 3 e 4 e a taxa de trabalho utilizada no processo.

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$$\begin{split} dU &= TdS - PdV + \sum_{i} \mu_{i} dN_{i} & dH = TdS + VdP + \sum_{i} \mu_{i} dN_{i} & dA = -SdT - PdV + \sum_{i} \mu_{i} dN_{i} \\ dG &= -SdT + VdP + \sum_{i} \mu_{i} dN_{i} & d\overline{H} = C_{p} dT + [\overline{V} - T \left(\frac{\partial \overline{V}}{\partial T}\right)_{p}] dP & d\overline{S} = \left(\frac{C_{p}}{T}\right) dT - \left(\frac{\partial \overline{V}}{\partial T}\right)_{p} dP \\ \left(\frac{\partial y}{\partial x}\right)_{z} \left(\frac{\partial x}{\partial z}\right)_{y} \left(\frac{\partial z}{\partial y}\right)_{x} = -1 & \Delta \overline{S}_{n}^{VAP} \left(cal / gmolK\right) = 8,0 + 1,987 \ln(T_{n}) \\ \frac{\Delta H_{2}^{VAP}}{\Delta H_{1}^{VAP}} &= \left(\frac{T_{2} - T_{C}}{T_{1} - T_{C}}\right)^{0.38} & R = 1,987 cal / (gmolK) = 82,05 (atmcm^{3}) / (gmolK) = 0,082 (atmL) / (gmolK) = 8,31 J / (gmolK) = 8,31 (LkPa) / (gmolK) = 0,0083 1 (M^{3}kPa) / (gmolK) \\ y_{i}P &= x_{i}\gamma_{i}P_{i}^{SAT} & \hat{a}_{i} &= \hat{f}_{f_{i}}^{0} & \hat{f}_{i} = x_{i} \hat{\phi}_{i} P = x_{i}\gamma_{i}f_{i}^{0} \\ \Delta \overline{G} &= RT(\sum_{i} x_{i} \ln \hat{a}_{i}) & K = \exp\left(\frac{-\Delta \overline{G}^{0}}{RT}\right) = \prod_{i} \hat{a}_{i}^{V_{i}} & \left(\frac{\partial \overline{G}}{T}\right)_{p} = -\frac{\overline{H}}{T^{2}} \\ \frac{d(mU)_{S}}{dt} &= \sum_{i} m_{j} (H_{j} + \frac{v_{j}^{2}}{2} + gz_{j}) - \sum_{i} m_{i} (H_{i} + \frac{v_{i}^{2}}{2} + gz_{i}) + \hat{Q} + \hat{W} \end{split}$$

Água saturada: tabela em função da pressão											
	Volume específico (m³/kg)		Energia interna (kJ/kg)			Entalpia (kJ/kg)			Entropia (kJ/kg K)		
Temp. °C	Líquido sat.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.
T	$v_l$	$V_{V}$	u <sub>I</sub>	$u_{lv}$	u <sub>v</sub>	h <sub>I</sub>	h <sub>Iv</sub>	$h_{v}$	Sı	$s_{lv}$	$s_{v}$
45,81	0,001010	14,67355	191,79	2246,10	2437,89	191,81	2392,82	2584,63	0,6492	7,5010	8,1501
53,97	0,001014	10,02218	225,90	2222,83	2448,73	225,91	2373,14	2599,06	0,7548	7,2536	8,0084
60,06	0,001017	7,64937	251,35	2205,36	2456,71	251,38	2358,33	2609,70	0,8319	7,0766	7,9085
64,97	0,001020	6,20424	271,88	2191,21	2463,08	271,90	2346,29	2618,19	0,8930	6,9383	7,8313
69,10	0,001022	5,22918	289,18	2179,22	2468,40	289,21	2336,07	2625,28	0,9439	6,8247	7,7686
75,87	0,001026	3,99345	317,51	2159,49	2477,00	317,55	2319,19	2636,74	1,0258	6,6441	7,6700
81,33	0,001030	3,24034	340,42	2143,43	2483,85	340,47	2305,40	2645,87	1,0910	6,5029	7,5939
91,77	0,001037	2,21711	394,29	2112,39	2496,67	384,36	2278,59	2662,96	1,2129	6,2434	7,4563
99,62	0,001043	1,69400	417,33	2088,72	2506,06	417,44	2258,02	2675,46	1,3025	6,0568	7,3593
105,99	0,001048	1,37490	444,16	2069,32	2513,48	444,30	2241,05	2685,35	1,3739	5,9104	7,2843
111,37	0,001053	1,15933	466,92	2052,72	2519,64	467,08	2226,46	2693,54	1,4335	5,7897	7,2232
116,06	0,001057	1,00363	486,78	2038,12	2524,90	486,97	2213,57	2700,53	1,4848	5,6868	7,1717
120,23	0,001061	0,88573	504,47	2025,02	2529,49	504,68	2201,96	2706,63	1,5300	5,5970	7,1271
124,00	0,001064	0,79325	520,45	2013,10	2533,56	520,69	2191,35	2712,04	1,5705	5,5173	7,0878
127,43	0,001067	0,71871	535,08	2002,14	2537,21	535,34	2181,55	2716,89	1,6072	5,4455	7,0526
130,60	0,001070	0,65731	548,57	1991,95	2540,53	548,87	2172,42	2721,29	1,6407	5,3801	7,0208
133,55	0,001073	0,60582	561,13	1982,43	2543,55	561,45	2163,85	2725,30	1,6717	5,3201	6,9918
	Temp. °C  T  45,81 53,97 60,06 64,97 69,10 75,87 81,33 91,77 99,62 105,99 111,37 116,06 120,23 124,00 127,43 130,60	Temp. Líquido sat.  T	Temp. °C         Líquido sat.         Vapor sat.           T         v/         v/           45,81         0,001010         14,67355           53,97         0,001014         10,02218           60,06         0,001017         7,64937           64,97         0,001020         6,20424           69,10         0,001022         5,22918           75,87         0,001026         3,99345           81,33         0,001030         3,24034           91,77         0,001037         2,21711           99,62         0,001043         1,69400           105,99         0,001048         1,37490           111,37         0,001053         1,15933           116,06         0,001057         1,00363           120,23         0,001061         0,88573           124,00         0,001064         0,79325           127,43         0,001067         0,71871           130,60         0,001070         0,65731	Temp. °C         Líquido sat.         Vapor sat.         Líquido sat.           T         v <sub>I</sub> v <sub>V</sub> u <sub>I</sub> 45,81         0,001010         14,67355         191,79           53,97         0,001014         10,02218         225,90           60,06         0,001017         7,64937         251,35           64,97         0,001020         6,20424         271,88           69,10         0,001022         5,22918         289,18           75,87         0,001026         3,99345         317,51           81,33         0,001030         3,24034         340,42           91,77         0,001037         2,21711         394,29           99,62         0,001043         1,69400         417,33           105,99         0,001048         1,37490         444,16           111,37         0,001053         1,15933         466,92           116,06         0,001057         1,00363         486,78           120,23         0,001061         0,88573         504,47           124,00         0,001064         0,79325         520,45           127,43         0,001067         0,71871         535,08           130,60 <td< td=""><td>Volume específico (m³/kg)         Energia intergia i</td><td>Volume específico (m³/kg)Energia interna (kJ/kg)Temp. °CLíquido sat.Vapor sat.Líquido sat.Evap.Vapor sat.T<math>v_l</math><math>v_v</math><math>u_l</math><math>u_{lv}</math><math>u_v</math>45,810,00101014,67355191,792246,102437,8953,970,00101410,02218225,902222,832448,7360,060,0010177,64937251,352205,362456,7164,970,0010206,20424271,882191,212463,0869,100,0010225,22918289,182179,222468,4075,870,0010263,99345317,512159,492477,0081,330,0010303,24034340,422143,432483,8591,770,0010372,21711394,292112,392496,6799,620,0010431,69400417,332088,722506,06105,990,0010481,37490444,162069,322513,48111,370,0010531,15933466,922052,722519,6416,060,0010571,00363486,782038,122524,90120,230,0010610,88573504,472025,022529,49124,000,0010640,79325520,452013,102533,56127,430,0010670,71871535,082002,14<t>2537,21130,600,0010700,65731548,571991,952540,53</t></td><td>Volume específico (m³/kg)Energia interna (kJ/kg)Temp. °CLíquido sat.Vapor sat.Líquido sat.Evap. sat.Vapor sat.Líquido sat.T<math>v_l</math><math>v_v</math><math>u_l</math><math>u_{lv}</math><math>u_v</math><math>h_l</math>45,810,00101014,67355191,792246,102437,89191,8153,970,00101410,02218225,902222,832448,73225,9160,060,0010177,64937251,352205,362456,71251,3864,970,0010206,20424271,882191,212463,08271,9069,100,0010225,22918289,182179,222468,40289,2175,870,0010263,99345317,512159,492477,00317,5581,330,0010303,24034340,422143,432483,85340,4791,770,0010372,21711394,292112,392496,67384,3699,620,0010431,69400417,332088,722506,06417,44105,990,0010481,37490444,162069,322513,48444,30111,370,0010531,15933466,922052,722519,64467,08120,230,0010610,88573504,472025,022529,49504,68124,000,0010640,79325520,452013,102533,56520,69127,430,0010670,71871535,082002,142537,21535,34130,600,00</td><td><math display="block"> \begin{array}{ c c c c c c c c c c c c c c c c c c c</math></td><td><math display="block"> \begin{array}{ c c c c c c c c c c c c c c c c c c c</math></td><td>Volume eye cifico (m³/kg)         Eyap. (kJ/kg)         Eyap. (kJ/kg)         Eyap. (kJ/kg)         Eyap. (kJ/kg)         Líquido sat.         Líquido sat</td><td>Volume específico (m³/kg)         Energia interna (kJ/kg)         Entropia (kJ/kg)         Evap.         Evap.         Líquido sat.         Evap.           45,81         0,0010101         14,67355         191,79         2246,10         2437,89         191,81         2392,82         2584,63         0,6492         7,5010         Ago 100     <!--</td--></td></td<>	Volume específico (m³/kg)         Energia intergia i	Volume específico (m³/kg)Energia interna (kJ/kg)Temp. °CLíquido sat.Vapor sat.Líquido sat.Evap.Vapor sat.T $v_l$ $v_v$ $u_l$ $u_{lv}$ $u_v$ 45,810,00101014,67355191,792246,102437,8953,970,00101410,02218225,902222,832448,7360,060,0010177,64937251,352205,362456,7164,970,0010206,20424271,882191,212463,0869,100,0010225,22918289,182179,222468,4075,870,0010263,99345317,512159,492477,0081,330,0010303,24034340,422143,432483,8591,770,0010372,21711394,292112,392496,6799,620,0010431,69400417,332088,722506,06105,990,0010481,37490444,162069,322513,48111,370,0010531,15933466,922052,722519,6416,060,0010571,00363486,782038,122524,90120,230,0010610,88573504,472025,022529,49124,000,0010640,79325520,452013,102533,56127,430,0010670,71871535,082002,14 <t>2537,21130,600,0010700,65731548,571991,952540,53</t>	Volume específico (m³/kg)Energia interna (kJ/kg)Temp. °CLíquido sat.Vapor sat.Líquido sat.Evap. sat.Vapor sat.Líquido sat.T $v_l$ $v_v$ $u_l$ $u_{lv}$ $u_v$ $h_l$ 45,810,00101014,67355191,792246,102437,89191,8153,970,00101410,02218225,902222,832448,73225,9160,060,0010177,64937251,352205,362456,71251,3864,970,0010206,20424271,882191,212463,08271,9069,100,0010225,22918289,182179,222468,40289,2175,870,0010263,99345317,512159,492477,00317,5581,330,0010303,24034340,422143,432483,85340,4791,770,0010372,21711394,292112,392496,67384,3699,620,0010431,69400417,332088,722506,06417,44105,990,0010481,37490444,162069,322513,48444,30111,370,0010531,15933466,922052,722519,64467,08120,230,0010610,88573504,472025,022529,49504,68124,000,0010640,79325520,452013,102533,56520,69127,430,0010670,71871535,082002,142537,21535,34130,600,00	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Volume eye cifico (m³/kg)         Eyap. (kJ/kg)         Eyap. (kJ/kg)         Eyap. (kJ/kg)         Eyap. (kJ/kg)         Líquido sat.         Líquido sat	Volume específico (m³/kg)         Energia interna (kJ/kg)         Entropia (kJ/kg)         Evap.         Evap.         Líquido sat.         Evap.           45,81         0,0010101         14,67355         191,79         2246,10         2437,89         191,81         2392,82         2584,63         0,6492         7,5010         Ago 100 </td

Vapor d'água superaquecido														
$\tau$	V	и	h	S	V	и	h	s	V	и	h	s		
1	(m³/kg)	(kJ/kg)	(kJ/kg)	(kJ/kg K)	(m³/kg)	(kJ/kg)	(kJ/kg)	(kJ/kg K)	(m³/kg)	(kJ/kg)	(kJ/kg)	(kJ/kg K)		
	P = 10 kPa (45,81)					<i>P</i> = 50 kPa (81,33)				<i>P</i> = 100 kPa (99,62)				
Sat.	14,67355	2437,89	2584,63	8,1501	3,24034	2483,85	2645,87	7,5939	1,69400	2506,06	2675,46	7,3593		
50	14,86920	2443,87	2592,56	8,1749	-	-	-	-	-	-	-	-		
100	17,19561	2515,50	2687,46	8,4479	3,41833	2511,61	2682,52	7,6947	-	-	-	-		
150	19,51251	2587,86	2782,99	8,6881	3,88937	2585,61	2780,08	7,9400	1,93636	2582,75	2776,38	7,6133		
200	21,82507	2661,27	2879,52	8,9037	4,35595	2659,85	2877,64	8,1579	2,17226	2658,05	2875,27	7,8342		
250	24,13559	2735,95	2977,31	9,1002	4,82045	2734,97	2975,99	8,3555	2,40604	2733,73	2974,33	8,0332		
300	26,44508	2812,06	3076,51	9,2812	5,28391	2811,33	3075,52	8,5372	2,63876	2810,41	3074,28	8,2157		
400	31,06252	2968,89	3279,51	9,6076	6,20929	2968,43	3278,89	8,8641	3,10263	2967,85	3278,11	8,5434		
500	35,67896	3132,26	3489,05	9,8977	7,13364	3131,94	3488,62	9,1545	3,56547	3131,54	3488,09	8,8341		
600	40,29488	3302,45	3705,40	10,1608	8,05748	3302,22	3705,10	9,4177	4,02781	3301,94	3704,72	9,0975		
700	44,91052	3479,63	3928,73	10,4028	8,98104	3479,45	3928,51	9,6599	4,48986	3479,24	3928,23	9,3398		

Tabela B.1.3