CH365 Chemical Engineering Thermodynamics

Lesson 32
Review

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Homework

This review focused on homework problems in problem set 11.

Problem 6.28

What is the mole fraction of water vapor in air that is saturated with water at 25 deg C and 101.33 kPa?

At 50 deg C and 101.33 kPa?

Problem 6.14

Estimate the entropy changes of vaporizations of benzene at 50 deg C. The vapor pressure of benzene is given by the equation

$$\ln\left(P^{sat}/\mathrm{kPa}\right) = 13.8858 - \frac{2788.51}{\left(t/\mathrm{deg\,C}\right) + 220.79}$$

(a) Use Eq. 6.86 with an estimated value of ΔVlv.
(b) Use the Clausius-Clapeyron equation from Example 6.6.

Report your answers in J/(mol-K).

Problem 6.83

(mixtures)

An equimolar mixture of methane and propane is discharged from a compressor at 5,500 kPa and 90 deg C at a rate of 1.4 kg/sec. If the velocity in the discharge line is not to exceed 30 m/sec, what is the minimum diameter of the discharge line?

Problem 6.25

Steam at 2,100 kPa and 260 deg C expands at constant enthalpy (as in a throttling process) to 125 kPa. What is the temperature of the steam in its final state and what is its entropy change? What would be the final temperature and entropy change for an ideal gas?

Study example 6.9 closely first

Problem 6.25

Steam at 2,100 kPa and 260 deg C expands at constant enthalpy (as in a throttling process) to 125 kPa. What is the temperature of the steam in its final state and what is its entropy change? What would be the final temperature and entropy change for an ideal gas?

Interpolation of points in steam tables

(x,y) is between (x_1,y_1) and (x_2,y_2)

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1}$$

Remember slope is constant between two points

Finding S_1 and H_1

$$\frac{260-250}{275-250}=\frac{S_1-6.5162}{6.6356-6.5162}$$

$$H_1 = 2923.5\ \frac{kJ}{kg}$$

$$S_1 = 6.5640\ \frac{kJ}{kg\cdot K}$$

TABLE E.2 Properties of Superheated Steam (Continued)

P/kPa (t^{sat}/°C)		sat. liq.	sat. vap.	TEMPERATURE: t°C (TEMPERATURE: T kelvins) 200 (473.15)	225 (498.15)	250 (523.15)	275 (548.15)	300 (573.15)	325 (598.15)	350 (623.15)	375 (648.15)
1750 (205.72)	V	1.166	113.38	.....	120.39	128.85	136.82	144.45	151.87	159.12	166.27
	U	876.234	2595.7	.....	2637.6	2687.7	2734.5	2779.3	2822.7	2865.3	2907.4
	H	878.274	2794.1	.....	2848.2	2913.2	2974.0	3032.1	3088.4	3143.7	3198.4
	S	2.3846	6.3853	.....	6.4961	6.6233	6.7368	6.8405	6.9368	7.0273	7.1133
1800 (207.11)	V	1.168	110.32	.....	116.69	124.99	132.78	140.24	147.48	154.55	161.51
	U	882.472	2596.3	.....	2635.5	2686.1	2733.3	2778.2	2821.8	2864.5	2906.7
	H	884.574	2794.8	.....	2845.5	2911.0	2972.3	3030.7	3087.3	3142.7	3197.5
	S	2.3976	6.3751	.....	6.4787	6.6071	6.7214	6.8257	6.9223	7.0131	7.0993
1850 (208.47)	V	1.170	107.41	.....	113.19	121.33	128.96	136.26	143.33	150.23	157.02
	U	888.585	2596.8	.....	2633.3	2684.4	2732.0	2777.2	2820.9	2863.8	2906.1
	H	890.750	2795.5	.....	2842.8	2908.9	2970.6	3029.3	3086.1	3141.7	3196.6
	S	2.4103	6.3651	.....	6.4616	6.5912	6.7064	6.8112	6.9082	6.9993	7.0856
1900 (209.80)	V	1.172	104.65	.....	109.87	117.87	125.35	132.49	139.39	146.14	152.76
	U	894.580	2597.3	.....	2631.2	2682.8	2730.7	2776.2	2820.1	2863.0	2905.4
	H	896.807	2796.1	.....	2840.0	2906.7	2968.8	3027.9	3084.9	3140.7	3195.7
	S	2.4228	6.3554	.....	6.4448	6.5757	6.6917	6.7970	6.8944	6.9857	7.0723
1950 (211.10)	V	1.174	102.031	.....	106.72	114.58	121.91	128.90	135.66	142.25	148.72
	U	900.461	2597.7	.....	2629.0	2681.1	2729.4	2775.1	2819.2	2862.3	2904.8
	H	902.752	2796.7	.....	2837.1	2904.6	2967.1	3026.5	3083.7	3139.7	3194.8
	S	2.4349	6.3459	.....	6.4283	6.5604	6.6772	6.7831	6.8809	6.9725	7.0593
2000 (212.37)	V	1.177	99.536	.....	103.72	111.45	118.65	125.50	132.11	138.56	144.89
	U	906.236	2598.2	.....	2626.9	2679.5	2728.1	2774.0	2818.3	2861.5	2904.1
	H	908.589	2797.2	.....	2834.3	2902.4	2965.4	3025.0	3082.5	3138.6	3193.9
	S	2.4469	6.3366	.....	6.4120	6.5454	6.6631	6.7696	6.8677	6.9596	7.0466
2100 (214.85)	V	1.181	94.890	.....	98.147	105.64	112.59	119.18	125.53	131.70	137.76
	U	917.479	2598.9	.....	2622.4	2676.1	2725.4	2771.9	2816.5	2860.0	2902.8
	H	919.959	2798.2	.....	2828.5	2897.9	2961.9	3022.2	3080.1	3136.6	3192.1
	S	2.4700	6.3187	.....	6.3802	6.5162	6.6356	6.7432	6.8422	6.9347	7.0220
2200 (217.24)	V	1.185	90.652	.....	93.067	100.35	107.07	113.43	119.53	125.47	131.28
	U	928.346	2599.6	.....	2617.9	2672.7	2722.7	2769.7	2814.7	2858.5	2901.5
	H	930.953	2799.1	.....	2822.7	2893.4	2958.3	3019.3	3077.7	3134.5	3190.3
	S	2.4922	6.3015	.....	6.3492	6.4879	6.6091	6.7179	6.8177	6.9107	6.9985
2300 (219.55)	V	1.189	86.769	.....	88.420	95.513	102.03	108.18	114.06	119.77	125.36
	U	938.866	2600.2	.....	2613.3	2669.2	2720.0	2767.6	2812.9	2857.0	2900.2
	H	941.601	2799.8	.....	2816.7	2888.9	2954.7	3016.4	3075.3	3132.4	3188.5
	S	2.5136	6.2849	.....	6.3190	6.4605	6.5835	6.6935	6.7941	6.8877	6.9759

Problem 6.25

Steam at 2,100 kPa and 260 deg C expands at constant enthalpy (as in a throttling process) to 125 kPa. What is the temperature of the steam in its final state and what is its entropy change? What would be the final temperature and entropy change for an ideal gas?

- T_1 = 260 degC
- P_1 = 2,100 kPa

- Superheated steam, Table E.2, page 705.
- Interpolate between 250 and 275 degC.

- S_1 = 6.5640 kJ/(kg·K)
- H_1 = 2,923.5 kJ/kg

- $H_2 = H_1$ = 2,923.5 kJ/kg
- P_2 = 125 kPa

Finding T_2 and S_2

$$\frac{T_2 - 200}{225 - 200} = \frac{2923.5 - 2874.2}{2923.9 - 2874.2}$$

$T_2 = 224.80\ ^{o}C$ $\quad S_2 = 7.8316\ \frac{kJ}{kg \cdot K}$

TABLE E.2 Properties of Superheated Steam

P/kPa (t^{sat}/°C)		sat. liq.	sat. vap.	TEMPERATURE: t°C (TEMPERATURE: T kelvins) 75 (348.15)	100 (373.15)	125 (398.15)	150 (423.15)	175 (448.15)	200 (473.15)	225 (498.15)	250 (523.15)
	V	1.044	1673.0	.....	1673.0	1792.7	1910.7	2027.7	2143.8	2259.3	2374.5
101.325	U	418.959	2506.5	.....	2506.5	2544.7	2582.6	2620.4	2658.1	2695.9	2733.9
(100.00)	H	419.064	2676.0	.....	2676.0	2726.4	2776.2	2825.8	2875.3	2924.8	2974.5
	S	1.3069	7.3554	.....	7.3554	7.4860	7.6075	7.7213	7.8288	7.9308	8.0280
	V	1.049	1374.6	.....	.....	1449.1	1545.6	1641.0	1735.6	1829.6	1923.2
125	U	444.224	2513.4	.....	.....	2542.9	2581.2	2619.3	2657.2	2695.2	2733.3
(105.99)	H	444.356	2685.2	.....	.....	2724.0	2774.4	2824.4	2874.2	2923.9	2973.7
	S	1.3740	7.2847	.....	.....	7.3844	7.5072	7.6219	7.7300	7.8324	7.9300
	V	1.053	1159.0	.....	.....	1204.0	1285.2	1365.2	1444.4	1523.0	1601.3
150	U	466.968	2519.5	.....	.....	2540.9	2579.7	2618.1	2656.3	2694.4	2732.7
(111.37)	H	467.126	2693.4	.....	.....	2721.5	2772.5	2822.9	2872.9	2922.9	2972.9
	S	1.4336	7.2234	.....	.....	7.2953	7.4194	7.5352	7.6439	7.7468	7.8447
	V	1.057	1003.34	.....	.....	1028.8	1099.1	1168.2	1236.4	1304.1	1371.3
175	U	486.815	2524.7	.....	.....	2538.9	2578.2	2616.9	2655.3	2693.7	2732.1
(116.06)	H	487.000	2700.3	.....	.....	2719.0	2770.5	2821.3	2871.7	2921.9	2972.0
	S	1.4849	7.1716	.....	.....	7.2191	7.3447	7.4614	7.5708	7.6741	7.7724
	V	1.061	885.44	.....	.....	897.47	959.54	1020.4	1080.4	1139.8	1198.9
200	U	504.489	2529.2	.....	.....	2536.9	2576.6	2615.7	2654.4	2692.9	2731.4
(120.23)	H	504.701	2706.3	.....	.....	2716.4	2768.5	2819.8	2870.5	2920.9	2971.2
	S	1.5301	7.1268	.....	.....	7.1523	7.2794	7.3971	7.5072	7.6110	7.7096
	V	1.064	792.97	.....	.....	795.25	850.97	905.44	959.06	1012.1	1064.7
225	U	520.465	2533.2	.....	.....	2534.8	2575.1	2614.5	2653.5	2692.2	2730.8
(123.99)	H	520.705	2711.6	.....	.....	2713.8	2766.5	2818.2	2869.3	2919.9	2970.4
	S	1.5705	7.0873	.....	.....	7.0928	7.2213	7.3400	7.4508	7.5551	7.6540
	V	1.068	718.44	.....	.....	.....	764.09	813.47	861.98	909.91	957.41
250	U	535.077	2536.8	.....	.....	.....	2573.5	2613.3	2652.5	2691.4	2730.2
(127.43)	H	535.343	2716.4	.....	.....	.....	2764.5	2816.7	2868.0	2918.9	2969.6
	S	1.6071	7.0520	.....	.....	.....	7.1689	7.2886	7.4001	7.5050	7.6042
	V	1.071	657.04	.....	.....	.....	693.00	738.21	782.55	826.29	869.61
275	U	548.564	2540.0	.....	.....	.....	2571.9	2612.1	2651.6	2690.7	2729.6
(130.60)	H	548.858	2720.7	.....	.....	.....	2762.5	2815.1	2866.8	2917.9	2968.7
	S	1.6407	7.0201	.....	.....	.....	7.1211	7.2419	7.3541	7.4594	7.5590
	V	1.073	605.56	.....	.....	.....	633.74	675.49	716.35	756.60	796.44
300	U	561.107	2543.0	.....	.....	.....	2570.3	2610.8	2650.6	2689.9	2729.0
(133.54)	H	561.429	2724.7	.....	.....	.....	2760.4	2813.5	2865.5	2916.9	2967.9
	S	1.6716	6.9909	.....	.....	.....	7.0771	7.1990	7.3119	7.4177	7.5176

Problem 6.25

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- T_1 = 260 degC
- P_1 = 2,100 kPa

- Superheated steam, Table E.2, page 705.
- Interpolate between 250 and 275 degC.

- S_1 = 6.5640 kJ/(kg·K)
- H_1 = 2,923.5 kJ/kg

- $H_2 = H_1$ = 2,923.5 kJ/kg
- P_2 = 125 kPa

- at 125 kPa and 200 deg C, H = 2,874.2 kJ/kg
- at 125 kPa and 225 deg C, H = 2,923.9 kJ/kg
- at 125 kPa and 250 deg C, H = 2,973.7 kJ/kg

- T_2 = 224.8 deg C

Problem 6.25

Steam at 2,100 kPa and 260 deg C expands at constant enthalpy (as in a throttling process) to 125 kPa. What is the temperature of the steam in its final state and what is its entropy change? What would be the final temperature and entropy change for an ideal gas?

- T_1 = 260 degC
- P_1 = 2,100 kPa

- Superheated steam, Table E.2, page 705.
- Interpolate between 250 and 275 degC.

- S_1 = 6.5640 kJ/(kg·K)
- P_2 = 125 kPa

- at 125 kPa and 200 deg C, S = 7.7300 kJ/(kg·K)
- at 125 kPa and 225 deg C, S = 7.8324 kJ/(kg·K)

- S_2 = 7.8316 kJ/(kg·K)
- ΔS = 7.8316 – 6.5640 = 1.2676 kJ/(kg·K)

Problem 6.25

Steam at 2,100 kPa and 260 deg C expands at constant enthalpy (as in a throttling process) to 125 kPa. What is the temperature of the steam in its final state and what is its entropy change? What would be the final temperature and entropy change for an ideal gas?

Ideal gas:

- T_1 = 260 degC
- P_1 = 2,100 kPa
- H_1 = 2,923.5 kJ/kg

- T_2 = ???
- P_2 = 125 kPa
- H_2 = 2,923.5 kJ/kg

$$\Delta H^{ig} = \int_{T_1}^{T_2} Cp\, dT$$

$$\Delta S^{ig} = \int_{T_1}^{T_2} \frac{Cp}{T} dT - Ln\left(\frac{P_2}{P_1}\right)$$

Equation 5.10