UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2004/2005

Mac 2005

EKC 222 – Termodinamik Kejuruteraan Kimia

Masa : 3 jam

Sila pastikan bahawa kertas peperiksaan ini mengandungi SEMBILAN muka surat yang bercetak dan SEMBILAN muka surat Lampiran sebelum anda memulakan peperiksaan ini.

Arahan: Kertas soalan ini mengandungi **ENAM (6)** soalan. Jawab mana-mana **LIMA (5)** soalan.

Pelajar boleh menjawab semua soalan dalam Bahasa Malaysia. Jika pelajar ingin menjawab dalam Bahasa Inggeris, pelajar hendaklah menjawab sekurang-kurangnya SATU soalan dalam Bahasa Malaysia.

Jawab mana-mana <u>LIMA</u> soalan.
Answer any FIVE questions.

1. [a] Stim pada suhu 225°C dan tekanan 1600 kPa dikembangkan melalui pendikit kepada tekanan 150 kPa. Anggarkan suhu dan keadaan stim yang keluar dari pendikit tersebut. (Gunakan jadual stim yang disediakan seperti di dalam Lampiran)

[4 markah]

[b] Udara pada suhu 300 K dan tekanan 15000 kPa dikembangkan menggunakan muncung mencapah menumpu yang sempurna kepada tekanan 1 bar. Dengan menganggap bahawa udara sebagai gas unggul, anggarkan suhu bagi udara yang keluar dari muncung tersebut. Diberi $\gamma = c_p/c_v = 1.4$ untuk udara.

[4 markah]

[c] Data tekanan wap (dalam Pascal) bagi benzena adalah seperti berikut:

Pepejal benzena: $ln\ P_s^{sat} = 27.841 - \dfrac{5295.8}{T}$

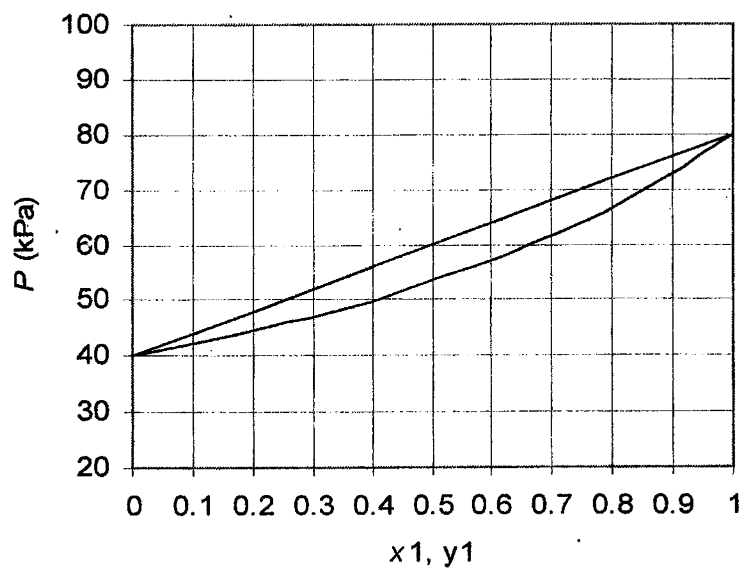
Cecair benzena: $ln\ P_l^{sat} = 22.98 - \dfrac{4035.7}{T}$

di mana T dalam Kelvin.

Kirakan titik tigaan bagi benzena dan haba pelakuran pada titik tigaan tersebut. Berapakah darjah kebebasan pada titik tigaan?

[4 markah]

[d] Gambarajah tekanan wap bagi sistem binari asetonitril (1)/nitrometana (2) pada suhu 74°C diberi seperti di bawah:



...3/-

Bagi sistem pada suhu 74°C, jawab soalan-soalan berikut:

[i] Komponen manakah yang mempunyai titik didih yang paling tinggi, asetonitril atau nitrometana?

[ii] Apakah keadaan fasa pada tekanan 60 kPa dan pecahan mol asetonitril sebanyak 0.5?

[iii] Jika larutan cecair yang mengandungi dua komponen mula mendidih pada tekanan 50 kPa, berapakah pecahan mol bagi asetonitril di dalam cecair pertama yang terpeluap?

[iv] Apakah kemeruwapan bagi asetonitril nisbi kepada nitrometana?

[4 markah]

[e] Dengan menggunakan gambarajah T-S, terangkan bagaimana penyejuk Carnot berfungsi.

[4 markah]

1. [a] Steam at 1600 kPa and 225°C is expanded through a throttle to a pressure of 150 kPa. Estimate the temperature and the condition of steam at the exit of the throttle. (Use steam tables provided in the Appendix)

[4 marks]

[b] Air at 15000 kPa and 300 K is expanded using a perfect converging diverging nozzle to pressure of 1 bar. Assuming air is an ideal gas, estimate the temperature of air at the outlet of the nozzle. Given $\gamma = c_p/c_v = 1.4$ for air.

[4 marks]

[c] The following vapor pressure data (in Pascal) are available for benzene:

Solid benzene: $\ln P_s^{sat} = 27.841 - \dfrac{5295.8}{T}$

Liquid benzene: $\ln P_l^{sat} = 22.98 - \dfrac{4035.7}{T}$

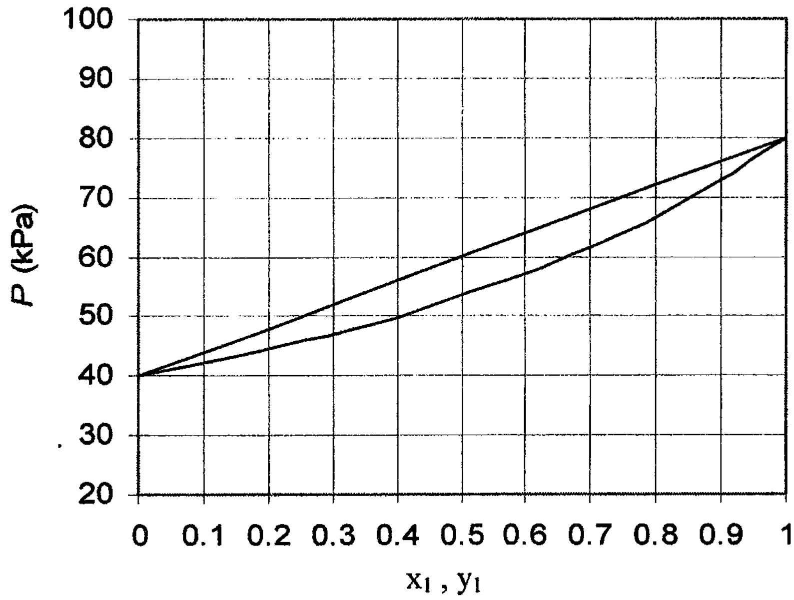
Where T is in Kelvin.

Compute the triple point of benzene and the heat of fusion at the triple point. What is the degree of freedom at the triple point?

[4 marks]

...4/-

[d] *The vapor pressure diagram of the binary system acetonitrile (1)/nitromethane (2) at 74°C is given below:*



For the system at 74°C, answer the following:

[i] *Which component has higher boiling point, acetonitrile or nitromethane?*

[ii] *What is the phase condition at 60 kPa and 0.5 mole fraction acetonitrile ?*

[iii] *If a liquid solution containing the two components starts to boil at 50 kPa, what is the mole fraction of acetonitrile in the first drop of liquid that vaporizes?*

[iv] *What is the volatility of aceto nitrite relative to nitro methane?*

[4 marks]

[e] *Using a T-S diagram, explain how a Carnot refrigerator works.*

[4 marks]

2. Karbon nanoserat boleh diperolehi daripada penguraian metana:

$$CH_4(g) = C(s) + 2H_2(g)$$

Metana tulen memasuki reaktor dan keseimbangan diperolehi pada suhu 700°C dan tekanan 1 bar. Anggapkan fasa gas pada keadaan tersebut adalah sebagai gas unggul.

...5/-

[a] Berapakah komposisi gas keluaran reaktor dan berapakah komposisi bagi metana yang terurai? Min haba tindak balas piawai bagi suhu di antara 25°C dan 700°C adalah 80,000 J/mol untuk CH_4 yang ditukarkan.

[6 markah]

[b] Bincangkan kesan bagi suhu, tekanan dan gas lengai dalam darjah keseimbangan untuk penguraian metana.

[4 markah]

[c] Gas keluaran dari reaktor dimampatkan secara sesuhu kepada keadaan akhir 700°C dan 10 bar untuk pemisahan membran. Jika gas tersebut mematuhi persamaan Redlich-Kwong pada keadaan akhirnya, apakah perubahan entalpi bagi gas selepas proses pemampatan?

Data berikut disediakan:

$\Delta H^{o}_{fCH4(g),25^{o}C} = -74,520 \text{ J mol}^{-1}$ $\quad\quad \Delta G^{o}_{fCH4(g),25^{o}C} = -50,460 \text{ J mol}^{-1}$

[Rumus dan data tambahan yang berkaitan disediakan seperti "Data Tambahan dan Persamaan" di dalam Lampiran]

[10 markah]

2. *Carbon nanofibers can be produced by the decomposition of methane:*

$$CH_4(g) = C(s) + 2H_2(g)$$

Pure methane enters the reactor and the equilibrium is attained at 700°C and 1 bar. Assume the gas phase is an ideal gas at this condition.

[a] What is the composition of the reactor outlet gas and what fraction of the methane decomposes? The mean standard heat of reaction between 25°C and 700°C is 80,000 J/mol of CH_4 converted.

[6 marks]

[b] Discuss the effects of temperature, pressure, and inert gas on the equilibrium extent of methane decomposition.

[4 marks]

[c] The outlet gas from the reactor is isothermally compressed to a final state of 700°C and 10 bar for membrane separation. If the gas obeys the Redlich-Kwong equation at its final state, what is the enthalpy change of the gas after the compression process?

The following data are available:

$\Delta H^{o}_{fCH4(g),25^{o}C} = -74,520 \text{ J mol}^{-1}$ $\quad\quad \Delta G^{o}_{fCH4(g),25^{o}C} = -50,460 \text{ J mol}^{-1}$

[Relevant formulae and additional data are given in "Additional Data and Equations" in the Appendix]

[10 marks]

...6/-

3. Untuk larutan binari etil asetat (1)/n-heptana (2), persamaan Margules satu parameter memberikan anggaran yang baik untuk pekali aktiviti:

$$\ln \gamma_1 = x_2^2 \qquad \ln \gamma_2 = x_1^2$$

Sebagai tambahan, persamaan Antoine berikut boleh digunakan untuk mengira tekanan wap:

$$\ln P_1^{sat} = 9.5314 - \frac{2790.5}{t+216} \qquad \ln P_2^{sat} = 9.2535 - \frac{2911.32}{t+216.64}$$

di mana P^{sat} adalah dalam unit bar dan t dalam unit °C.

Dengan menganggap kesahihan hukum Raoult terubahsuai yang mengambilkira ketakunggulan bagi fasa cecair:

[a] Kirakan tekanan titik gelembung untuk cecair yang mengandungi 0.2 pecahan mol etil asetat pada 60°C dan komposisi untuk gelembung pertama bagi wap terbentuk

[6 markah]

[b] Kirakan tekanan tertinggi di mana campuran mengandungi 0.2 pecahan mol etil asetat boleh wujud sebagai wap pada suhu 60°C tanpa pemeluwapan? (Tunjukkan hanya satu lelaran bermula dari larutan unggul).

[7 markah]

[c] Kirakan komposisi bagi fasa wap dan cecair dalam keseimbangan pada suhu 60°C dan tekanan 0.4 bar. (Bermula dengan nilai $x_1 = 0.2$ dan tunjukkan dua lelaran).

[7 markah]

3. *For the binary solution of ethyl acetate (1)/n-heptane (2), the one-parameter Margules equation gives a good approximation for the activity coefficients:*

$$\ln \gamma_1 = x_2^2 \qquad \ln \gamma_2 = x_1^2$$

In addition, the following Antoine equations provide vapor pressures:

$$\ln P_1^{sat} = 9.5314 - \frac{2790.5}{t+216} \qquad \ln P_2^{sat} = 9.2535 - \frac{2911.32}{t+216.64}$$

where P^{sat} is in bar and t in °C.

Assuming the validity of the modified Raoult's law that takes into account nonideality of the liquid phase,

...7/-

[a] Calculate the bubble point pressure for the liquid containing 0.2 mole fraction ethyl acetate at 60°C, and the composition of the first bubble of vapor appeared.

[6 marks]

[b] What is the highest pressure at which the mixture containing 0.2 mole fraction ethyl acetate can exist as vapor at 60°C without condensing? (Show only one iteration starting from ideal solution)

[7 marks]

[c] Calculate the compositions of the vapor and liquid phases in equilibrium at 60°C and 0.4 bar. (Start with initial value of x_1 = 0.2 and show two iterations)

[7 marks]

4. Sebuah tangki penyimpanan berisipadu 8 m^3 (isipadu keseluruhan) mengandungi 500 kg cecair air yang pada mulanya disimpan di bawah tekanan 19.92 kPa dan suhu 60°C. Ruang bahagian atas tangki hanya mengandungi wap air di mana dalam keadaan keseimbangan dengan cecair air di dalam tangki. Sebanyak 500 kg air pada suhu 90°C disuapkan ke dalam tangki tersebut dan tangki ini kemudiannya dikekalkan suhunya pada 100°C dan tekanan 101.33 kPa. Anggarkan jumlah terakhir wap air dan cecair air yang wujud di dalam tangki tersebut. ***[Gunakan jadual wap yang disediakan di dalam Appendix]***.

[20 markah]

4. *A storage tank of 8 m^3 (total volume) containing 500 kg of liquid water is initially kept under a pressure of 19.92 kPa and 60°C. The space above the tank contains only water vapour which is in equilibrium with the liquid water in the tank. Another 500 kg of water at 90°C is fed to the tank and the tank is thereafter maintained at 100°C and 101.33 kPa. Estimate the final amount of water vapour and the liquid water present in the tank.* ***[Use steam tables provided in the Appendix]***

[20 marks]

5. [a] Anggarkan fugasiti bagi sulfur trioksida (SO_3) pada suhu 25°C dan tekanan 1 bar.
Untuk SO_3 T_c = 490.9 K, P_c = 82.10 bar dan ω = Faktor Tak Sepusat = 0.424.

Data untuk ϕ^o dan ϕ^1 bagi pelbagai nilai P_r dan T_r disediakan seperti di dalam Jadual S.5 di dalam Lampiran.
Diberi $\phi = \phi^o . (\phi^1)^{\omega}$

[8 markah]

...8/-

[b] Anggarkan perubahan tenaga apabila 1 mol SO_3 pada suhu 25°C ditindakbalaskan dengan air tulen (cecair) pada suhu 30°C untuk mendapatkan larutan asid sulfurik sebanyak 60% mengikut berat pada suhu 60°C. Tindakbalas boleh dianggapkan sebagai

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

Nilai ΔH^o_{f298} untuk SO_3, H_2O (cecair) dan H_2SO_4 (cecair) diberi seperti di dalam jadual dibawah. Graf entalpi untuk larutan H_2SO_4 lawan kepekatan larutan H_2SO_4 disediakan seperti di dalam gambarajah S.5 di dalam Lampiran.

Jadual: Nilai untuk ΔH^o_{f298}

	SO_3	H_2O (cecair)	H_2SO_4 (cecair)
ΔH^o_{f298} J/mol	-441040	-285830	-813989

Berat Atom : H = 1 , S = 32 , O = 16

[12 marks]

5. *[a] Estimate the fugacity of sulphur trioxide (SO_3) at 25°C and 1 bar.*
For SO_3 $T_c = 490.9$ K, $P_c = 82.10$ bar and ω = Acentric factor = 0.424.
Data for ϕ^o and ϕ^1 for various P_r and T_r are provided in Table Q.5 in the Appendix.
Given $\phi = \phi^o . (\phi^1)^\omega$

[8 marks]

[b] Estimate the heat change when 1 mole of SO_3 at 25°C is made to react with pure water (liquid) at 30°C to obtain sulphuric acid solution of 60% by weight at 60°C. The reaction may be assumed as

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

ΔH^o_{f298} values for SO_3, H_2O (liquid) and H_2SO_4 (liquid) are given in the Table below. A graph of enthalpy of H_2SO_4 solutions vs concentration is provided in Figure Q. 5 in the Appendix.

Table: Values of ΔH^o_{f298}

	SO_3	H_2O (liquid)	H_2SO_4 (liquid)
ΔH^o_{f298} J/mole	-441040	-285830	-813989

Atomic weight : H = 1 , S = 32 , O = 16

[12 marks]

...9/-

6. [a] Kitar unggul penyejukan menggunakan R-134a sebagai cecair bekerja. Suhu bagi bahan penyejuk di dalam penyejat adalah -20°C manakala di dalam pemeluwap adalah 40°C. Bahan penyejuk dikitar pada kadar 0.03 kg/s.

[i] Tentukan pekali prestasi bagi penyejukan ini.

[ii] Tentukan kapasiti loji bedasarkan kadar penyejukan.

Nota: Lakarkan diagram T-S untuk membantu anda menyelesaikan masalah ini. Gunakan Jadual 6 [a] [i] dan 6 [a] [ii] yang terdapat di dalam Lampiran untuk soalan ini.

[10 markah]

[b] [i] Apakah proses pencairan? Berikan tiga cara bagaimana proses ini boleh dicapai.

[4 markah]

[ii] Dengan menggunakan diagram T-S, terangkan bagaimana proses pencairan dapat dicapai.

[6 markah]

6. [a] An ideal refrigeration cycle uses R-134a as the working fluid. The temperature of the refrigerant in the evaporator is -20°C and in the condenser is 40°C. The refrigerant is circulated at the rate of 0.03 kg/s.

[i] Determine the coefficient of performance of the refrigeration.

[ii] Determine the capacity of the plant in terms of refrigeration rate.

Note: Draw a T-S diagram to help you to solve the problem.
Use Table 6 [a] [i] and 6 [a] [ii] in the Appendix for this question.

[10 marks]

[b] [i] What is a liquefaction processes? Give 3 ways of how it can be accomplished.

[4 marks]

[ii] Using a T-S diagram, explain how liquefaction processes can be accomplished.

[6 marks]

- ooo O ooo -

Lampiran

DATA FOR QUESTION 1(a)

Superheated Steam, SI Units

V = SPECIFIC VOLUME $cm^3\ g^{-1}$
U = SPECIFIC INTERNAL ENERGY $kJ\ kg^{-1}$
H = SPECIFIC ENTHALPY $kJ\ kg^{-1}$
S = SPECIFIC ENTROPY $kJ\ kg^{-1}\ K^{-1}$

TEMPERATURE: t °C (TEMPERATURE: T kelvins)

P/kPa (t^{sat}/°C)		sat. liq.	sat. vap.	300 (573.15)	350 (623.15)	400 (673.15)	450 (723.15)	500 (773.15)	550 (823.15)	600 (873.15)	650 (923.15)
	V	1.000	129200.	264500.	287580.	310660.	333730.	356810.	379880.	402960.	426040.
1	U	29.334	2385.2	2812.3	2889.9	2969.1	3049.9	3132.4	3216.7	3302.6	3390.3
(6.98)	H	29.335	2514.4	3076.8	3177.5	3279.7	3383.6	3489.2	3596.5	3705.6	3816.4
	S	0.1060	8.9767	10.3450	10.5133	10.6711	10.8200	10.9612	11.0957	11.2243	11.3476
	V	1.010	14670.	26440.	28750.	31060.	33370.	35670.	37980.	40290.	42600.
10	U	191.822	2438.0	2812.2	2889.8	2969.0	3049.8	3132.3	3216.6	3302.6	3390.3
(45.83)	H	191.832	2584.8	3076.6	3177.3	3279.6	3383.5	3489.1	3596.5	3705.5	3816.3
	S	0.6493	8.1511	9.2820	9.4504	9.6083	9.7572	9.8984	10.0329	10.1616	10.2849
	V	1.017	7649.8	13210.	14370.	15520.	16680.	17830.	18990.	20140.	21300.
20	U	251.432	2456.9	2812.0	2889.6	2968.9	3049.7	3132.3	3216.5	3302.5	3390.2
(60.09)	H	251.453	2609.9	3076.4	3177.1	3279.4	3383.4	3489.0	3596.4	3705.4	3816.2
	S	0.8321	7.9094	8.9618	9.1303	9.2882	9.4372	9.5784	9.7130	9.8416	9.9650
	V	1.022	5229.3	8810.8	9581.2	10350.	11120.	11890.	12660.	13430.	14190.
30	U	289.271	2468.6	2811.8	2889.5	2968.7	3049.6	3132.2	3216.5	3302.5	3390.2
(69.12)	H	289.302	2625.4	3076.1	3176.9	3279.3	3383.3	3488.9	3596.3	3705.4	3816.2
	S	0.9441	7.7695	8.7744	8.9430	9.1010	9.2499	9.3912	9.5257	9.6544	9.7778
	V	1.027	3993.4	6606.5	7184.6	7762.5	8340.1	8917.6	9494.9	10070.	10640.
40	U	317.609	2477.1	2811.6	2889.4	2968.6	3049.5	3132.1	3216.4	3302.4	3390.1
(75.89)	H	317.650	2636.9	3075.9	3176.8	3279.1	3383.1	3488.8	3596.2	3705.3	3816.1
	S	1.0261	7.6709	8.6413	8.8100	8.9680	9.1170	9.2583	9.3929	9.5216	9.6450
	V	1.030	3240.2	5283.9	5746.7	6209.1	6671.4	7133.5	7595.5	8057.4	8519.2
50	U	340.513	2484.0	2811.5	2889.2	2968.5	3049.4	3132.0	3216.3	3302.3	3390.1
(81.35)	H	340.564	2646.0	3075.7	3176.6	3279.0	3383.0	3488.7	3596.1	3705.2	3816.0
	S	1.0912	7.5947	8.5380	8.7068	8.8649	9.0139	9.1552	9.2898	9.4185	9.5419
	V	1.037	2216.9	3520.5	3829.4	4138.0	4446.4	4754.7	5062.8	5370.9	5678.9
75	U	384.374	2496.7	2811.0	2888.9	2968.2	3049.2	3131.8	3216.1	3302.2	3389.9
(91.79)	H	384.451	2663.0	3075.1	3176.1	3278.6	3382.7	3488.4	3595.8	3705.0	3815.9
	S	1.2131	7.4570	8.3502	8.5191	8.6773	8.8265	8.9678	9.1025	9.2312	9.3546
	V	1.043	1693.7	2638.7	2870.8	3102.5	3334.0	3565.3	3796.5	4027.7	4258.8
100	U	417.406	2506.1	2810.6	2888.6	2968.0	3049.0	3131.6	3216.0	3302.0	3389.8
(99.63)	H	417.511	2675.4	3074.5	3175.6	3278.2	3382.4	3488.1	3595.6	3704.8	3815.7
	S	1.3027	7.3598	8.2166	8.3858	8.5442	8.6934	8.8348	8.9695	9.0982	9.2217
	V	1.044	1673.0	2604.2	2833.2	3061.9	3290.3	3518.7	3746.9	3975.0	4203.1
101.325	U	418.959	2506.5	2810.6	2888.5	2968.0	3048.9	3131.6	3215.9	3302.0	3389.8
(100.00)	H	419.064	2676.0	3074.4	3175.6	3278.2	3382.3	3488.1	3595.6	3704.8	3815.7
	S	1.3069	7.3554	8.2105	8.3797	8.5381	8.6873	8.8287	8.9634	9.0922	9.2156
	V	1.049	1374.6	2109.7	2295.6	2481.2	2666.5	2851.7	3036.8	3221.8	3406.7
125	U	444.224	2513.4	2810.2	2888.2	2967.7	3048.7	3131.4	3215.8	3301.9	3389.7
(105.99)	H	444.356	2685.2	3073.9	3175.2	3277.8	3382.0	3487.9	3595.4	3704.6	3815.5
	S	1.3740	7.2847	8.1129	8.2823	8.4408	8.5901	8.7316	8.8663	8.9951	9.1186
	V	1.053	1159.0	1757.0	1912.2	2066.9	2221.5	2375.9	2530.2	2684.5	2838.6
150	U	466.968	2519.5	2809.7	2887.9	2967.4	3048.5	3131.2	3215.6	3301.7	3389.5
(111.37)	H	467.126	2693.4	3073.3	3174.7	3277.5	3381.7	3487.6	3595.1	3704.4	3815.3
	S	1.4336	7.2234	8.0280	8.1976	8.3562	8.5056	8.6472	8.7819	8.9108	9.0343
	V	1.057	1003.34	1505.1	1638.3	1771.1	1903.7	2036.1	2168.4	2300.7	2432.9
175	U	486.815	2524.7	2809.3	2887.5	2967.1	3048.3	3131.0	3215.4	3301.6	3389.4
(116.06)	H	487.000	2700.3	3072.7	3174.2	3277.1	3381.4	3487.3	3594.9	3704.2	3815.1
	S	1.4849	7.1716	7.9561	8.1259	8.2847	8.4341	8.5758	8.7106	8.8394	8.9630
	V	1.061	885.44	1316.2	1432.8	1549.2	1665.3	1781.2	1897.1	2012.9	2128.6
200	U	504.489	2529.2	2808.8	2887.2	2966.9	3048.0	3130.8	3215.3	3301.4	3389.2
(120.23)	H	504.701	2706.3	3072.1	3173.8	3276.7	3381.1	3487.0	3594.7	3704.0	3815.0
	S	1.5301	7.1268	7.8937	8.0638	8.2226	8.3722	8.5139	8.6487	8.7776	8.9012
	V	1.064	792.97	1169.2	1273.1	1376.6	1479.9	1583.0	1686.0	1789.0	1891.9
225	U	520.465	2533.2	2808.4	2886.9	2966.6	3047.8	3130.6	3215.1	3301.2	3389.1
(123.99)	H	520.705	2711.6	3071.5	3173.3	3276.3	3380.8	3486.8	3594.4	3703.8	3814.8
	S	1.5705	7.0873	7.8385	8.0088	8.1679	8.3175	8.4593	8.5942	8.7231	8.8467
	V	1.068	718.44	1051.6	1145.2	1238.5	1331.5	1424.4	1517.2	1609.9	1702.5
250	U	535.077	2536.8	2808.0	2886.5	2966.3	3047.6	3130.4	3214.9	3301.1	3389.0
(127.43)	H	535.343	2716.4	3070.9	3172.8	3275.9	3380.4	3486.5	3594.2	3703.6	3814.6
	S	1.6071	7.0520	7.7891	7.9597	8.1188	8.2686	8.4104	8.5453	8.6743	8.7980
	V	1.071	657.04	955.45	1040.7	1125.5	1210.2	1294.7	1379.0	1463.3	1547.6
275	U	548.564	2540.0	2807.5	2886.2	2966.0	3047.3	3130.2	3214.7	3300.9	3388.8
(130.60)	H	548.858	2720.7	3070.3	3172.4	3275.5	3380.1	3486.2	3594.0	3703.4	3814.4
	S	1.6407	7.0201	7.7444	7.9151	8.0744	8.2243	8.3661	8.5011	8.6301	8.7538
	V	1.073	605.56	875.29	953.52	1031.4	1109.0	1186.5	1263.9	1341.2	1418.5
300	U	561.107	2543.0	2807.1	2885.8	2965.8	3047.1	3130.0	3214.5	3300.8	3388.7
(133.54)	H	561.429	2724.7	3069.7	3171.9	3275.2	3379.8	3486.0	3593.7	3703.2	3814.2
	S	1.6716	6.9909	7.7034	7.8744	8.0338	8.1838	8.3257	8.4608	8.5898	8.7135

...2/-

DATA FOR QUESTION 1(a)

Superheated Steam, SI Units

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)
1350	V	1.146	145.74	148.79	159.70	169.96	179.79	189.33	198.66	207.85	216.93
(193.35)	U	820.944	2589.9	2603.9	2653.6	2700.1	2744.4	2787.4	2829.5	2871.1	2912.5
	H	822.491	2786.6	2804.7	2869.2	2929.5	2987.1	3043.0	3097.7	3151.7	3205.4
	S	2.2676	6.4780	6.5165	6.6493	6.7675	6.8750	6.9746	7.0681	7.1566	7.2410
1400	V	1.149	140.72	142.94	153.57	163.55	173.08	182.32	191.35	200.24	209.02
(195.04)	U	828.465	2590.8	2601.3	2651.7	2698.6	2743.2	2786.4	2828.6	2870.4	2911.9
	H	830.074	2787.8	2801.4	2866.7	2927.6	2985.5	3041.6	3096.5	3150.7	3204.5
	S	2.2837	6.4651	6.4941	6.6285	6.7477	6.8560	6.9561	7.0499	7.1386	7.2233
1450	V	1.151	136.04	137.48	147.86	157.57	166.83	175.79	184.54	193.15	201.65
(196.69)	U	835.791	2591.6	2598.7	2649.7	2697.1	2742.0	2785.4	2827.8	2869.7	2911.3
	H	837.460	2788.9	2798.1	2864.1	2925.5	2983.9	3040.3	3095.4	3149.7	3203.6
	S	2.2993	6.4526	6.4722	6.6082	6.7286	6.8376	6.9381	7.0322	7.1212	7.2061
1500	V	1.154	131.66	132.38	142.53	151.99	161.00	169.70	178.19	186.53	194.77
(198.29)	U	842.933	2592.4	2596.1	2647.7	2695.5	2740.8	2784.4	2826.9	2868.9	2910.6
	H	844.663	2789.9	2794.7	2861.5	2923.5	2982.3	3038.9	3094.2	3148.7	3202.8
	S	2.3145	6.4406	6.4508	6.5885	6.7099	6.8196	6.9207	7.0152	7.1044	7.1894
1550	V	1.156	127.55	127.61	137.54	146.77	155.54	164.00	172.25	180.34	188.33
(199.85)	U	849.901	2593.2	2593.5	2645.8	2694.0	2739.5	2783.4	2826.1	2868.2	2910.0
	H	851.694	2790.8	2791.3	2858.9	2921.5	2980.6	3037.6	3093.1	3147.7	3201.9
	S	2.3292	6.4289	6.4298	6.5692	6.6917	6.8022	6.9038	6.9986	7.0881	7.1733
1600	V	1.159	123.69	....	132.85	141.87	150.42	158.66	166.68	174.54	182.30
(201.37)	U	856.707	2593.8	....	2643.7	2692.4	2738.3	2782.4	2825.2	2867.5	2909.3
	H	858.561	2791.7	....	2856.3	2919.4	2979.0	3036.2	3091.9	3146.7	3201.0
	S	2.3436	6.4175	....	6.5503	6.6740	6.7852	6.8873	6.9825	7.0723	7.1577
1650	V	1.161	120.05	....	128.45	137.27	145.61	153.64	161.44	169.09	176.63
(202.86)	U	863.359	2594.5	....	2641.7	2690.9	2737.1	2781.3	2824.4	2866.7	2908.7
	H	865.275	2792.6	....	2853.6	2917.4	2977.3	3034.8	3090.8	3145.7	3200.1
	S	2.3576	6.4065	....	6.5319	6.6567	6.7687	6.8713	6.9669	7.0569	7.1425
1700	V	1.163	116.62	....	124.31	132.94	141.09	148.91	156.51	163.96	171.30
(204.31)	U	869.866	2595.1	....	2639.6	2689.3	2735.8	2780.3	2823.5	2866.0	2908.0
	H	871.843	2793.4	....	2851.0	2915.3	2975.6	3033.5	3089.6	3144.7	3199.2
	S	2.3713	6.3957	....	6.5138	6.6398	6.7526	6.8557	6.9516	7.0419	7.1277
1750	V	1.166	113.38	....	120.39	128.85	136.82	144.45	151.87	159.12	166.27
(205.72)	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	V	1.168	110.32	....	116.69	124.99	132.78	140.24	147.48	154.55	161.51
(207.11)	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	V	1.170	107.41	....	113.19	121.33	128.96	136.26	143.33	150.23	157.02
(208.47)	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	V	1.172	104.65	....	109.87	117.87	125.35	132.49	139.39	146.14	152.76
(209.80)	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	V	1.174	102.031	....	106.72	114.58	121.91	128.90	135.66	142.25	148.72
(211.10)	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	V	1.177	99.536	....	103.72	111.45	118.65	125.50	132.11	138.56	144.89
(212.37)	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	V	1.181	94.890	....	98.147	105.64	112.59	119.18	125.53	131.70	137.76
(214.85)	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	V	1.185	90.652	....	93.067	100.35	107.07	113.43	119.53	125.47	131.28
(217.24)	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	V	1.189	86.769	....	88.420	95.513	102.03	108.18	114.06	119.77	125.36
(219.55)	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

...3/-

Additional Data and Equations

The Redlich-Kwong EOS in terms of compressibility factor suitable for vapor root:

$$Z = 1 + \beta - \frac{q\beta(Z-\beta)}{Z(Z+\beta)} \quad \text{where} \quad \beta \equiv \frac{bP}{RT} \quad \text{and} \quad q \equiv \frac{a}{bRT}$$

$$a = \sum_i \sum_j y_i y_j (a_i a_j)^{1/2} = \left(\sum_i y_i a_i^{1/2}\right)^2, \qquad b = \sum_i y_i b_i$$

$$a_i = \frac{0.42748\, T_{ri}^{-0.5} R^2 T_{ci}^2}{P_{ci}} \qquad b_i = \frac{0.08664\, RT_{ci}}{P_{ci}}$$

The critical constants for methane: $T_c = 190.6$ K $\quad P_c = 45.99$ bar $\quad \omega = 0.012$

The critical constants for hydrogen: $T_c = 33.19$ K $\quad P_c = 13.13$ bar $\quad \omega = -0.216$

Residual properties from Redlich-Kwong EOS

$$\frac{H^R}{RT} = Z - 1 - \frac{3q}{2}\ln\frac{Z+\beta}{Z} \qquad \frac{S^R}{R} = \ln(Z-\beta) - \frac{q}{2}\ln\frac{Z+\beta}{Z}$$

Property changes of a gas between two state points:

$$\Delta H = \left\langle C_P^{ig} \right\rangle_H (T_2 - T_1) + H_2^R - H_1^R \qquad \Delta S = \left\langle C_P^{ig} \right\rangle_S \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1} + S_2^R - S_1^R$$

Mean ideal gas heat capacities between temperatures T_1 and T_2:

$$\frac{\left\langle C_P^{ig} \right\rangle_H}{R} = A + \frac{B}{2}T_1(\tau+1) + \frac{C}{3}T_1^2(\tau^2+\tau+1) + \frac{D}{\tau T_1^2}$$

$$\frac{\left\langle C_P^{ig} \right\rangle_S}{R} = A + \left[BT_1 + \left(CT_1^2 + \frac{D}{\tau^2 T_1^2}\right)\left(\frac{\tau+1}{2}\right)\right]\left(\frac{\tau-1}{\ln\tau}\right) \qquad \text{where} \quad \tau = \frac{T_2}{T_1}$$

For methane:	$A = 1.702$	$B = 9.081\text{x}10^{-3}$	$C = -2.164\text{x}10^{-6}$	$D = 0$
For carbon:	$A = 1.771$	$B = 0.771\text{x}10^{-3}$	$C = 0$	$D = -0.867\text{x}10^{5}$
For hydrogen:	$A = 3.249$	$B = 0.422\text{x}10^{-3}$	$C = 0$	$D = 0.083\text{x}10^{5}$

Clausius-Clapeyron Equation:

$$\ln P^{sat} = -\frac{\Delta H^{lv}}{RT} + C$$

Effect of temperature on equilibrium constant:

$$\ln\frac{K_2}{K_1} = \frac{\Delta H_{rxn}^0 (T_2 - T_1)}{RT_1T_2}$$

Universal gas constant: $R = 8.314$ J mol^{-1}K^{-1}

...4/-

DATA FOR QUESTION 4

Table F.1: Saturated Steam, SI Units

V = SPECIFIC VOLUME cm^3 g^{-1}
U = SPECIFIC INTERNAL ENERGY kJ kg^{-1}
H = SPECIFIC ENTHALPY kJ kg^{-1}
S = SPECIFIC ENTROPY kJ kg^{-1} K^{-1}

			SPECIFIC VOLUME V			INTERNAL ENERGY U			ENTHALPY H			ENTROPY S		
t °C	T K	P kPa	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.
0	273.15	0.611	1.000	206300.	206300.	-0.04	2375.7	2375.6	-0.04	2501.7	2501.6	0.0000	9.1578	9.1578
0.01	273.16	0.611	1.000	206200.	206200.	0.00	2375.6	2375.6	0.00	2501.6	2501.6	0.0000	9.1575	9.1575
1	274.15	0.657	1.000	192600.	192600.	4.17	2372.7	2376.9	4.17	2499.2	2503.4	0.0153	9.1158	9.1311
2	275.15	0.705	1.000	179900.	179900.	8.39	2369.9	2378.3	8.39	2496.8	2505.2	0.0306	9.0741	9.1047
3	276.15	0.757	1.000	168200.	168200.	12.60	2367.1	2379.7	12.60	2494.5	2507.1	0.0459	9.0326	9.0785
4	277.15	0.813	1.000	157300.	157300.	16.80	2364.3	2381.1	16.80	2492.1	2508.9	0.0611	8.9915	9.0526
5	278.15	0.872	1.000	147200.	147200.	21.01	2361.4	2382.4	21.01	2489.7	2510.7	0.0762	8.9507	9.0269
6	279.15	0.935	1.000	137800.	137800.	25.21	2358.6	2383.8	25.21	2487.4	2512.6	0.0913	8.9102	9.0014
7	280.15	1.001	1.000	129100.	129100.	29.41	2355.8	2385.2	29.41	2485.0	2514.4	0.1063	8.8699	8.9762
8	281.15	1.072	1.000	121000.	121000.	33.60	2353.0	2386.6	33.60	2482.6	2516.2	0.1213	8.8300	8.9513
9	282.15	1.147	1.000	113400.	113400.	37.80	2350.1	2387.9	37.80	2480.3	2518.1	0.1362	8.7903	8.9265
10	283.15	1.227	1.000	106400.	106400.	41.99	2347.3	2389.3	41.99	2477.9	2519.9	0.1510	8.7510	8.9020
11	284.15	1.312	1.000	99910.	99910.	46.18	2344.5	2390.7	46.19	2475.5	2521.7	0.1658	8.7119	8.8776
12	285.15	1.401	1.000	93830.	93840.	50.38	2341.7	2392.1	50.38	2473.2	2523.6	0.1805	8.6731	8.8536
13	286.15	1.497	1.001	88180.	88180.	54.56	2338.9	2393.4	54.57	2470.8	2525.4	0.1952	8.6345	8.8297
14	287.15	1.597	1.001	82900.	82900.	58.75	2336.1	2394.8	58.75	2468.5	2527.2	0.2098	8.5963	8.8060
15	288.15	1.704	1.001	77980.	77980.	62.94	2333.2	2396.2	62.94	2466.1	2529.1	0.2243	8.5582	8.7826
16	289.15	1.817	1.001	73380.	73380.	67.12	2330.4	2397.6	67.13	2463.8	2530.9	0.2388	8.5205	8.7593
17	290.15	1.936	1.001	69090.	69090.	71.31	2327.6	2398.9	71.31	2461.4	2532.7	0.2533	8.4830	8.7363
18	291.15	2.062	1.001	65090.	65090.	75.49	2324.8	2400.3	75.50	2459.0	2534.5	0.2677	8.4458	8.7135
19	292.15	2.196	1.002	61340.	61340.	79.68	2322.0	2401.7	79.68	2456.7	2536.4	0.2820	8.4088	8.6908
20	293.15	2.337	1.002	57840.	57840.	83.86	2319.2	2403.0	83.86	2454.3	2538.2	0.2963	8.3721	8.6684
21	294.15	2.485	1.002	54560.	54560.	88.04	2316.4	2404.4	88.04	2452.0	2540.0	0.3105	8.3356	8.6462
22	295.15	2.642	1.002	51490.	51490.	92.22	2313.6	2405.8	92.23	2449.6	2541.8	0.3247	8.2994	8.6241
23	296.15	2.808	1.002	48620.	48620.	96.40	2310.7	2407.1	96.41	2447.2	2543.6	0.3389	8.2634	8.6023
24	297.15	2.982	1.003	45920.	45930.	100.6	2307.9	2408.5	100.6	2444.9	2545.5	0.3530	8.2277	8.5806
25	298.15	3.166	1.003	43400.	43400.	104.8	2305.1	2409.9	104.8	2442.5	2547.3	0.3670	8.1922	8.5592
26	299.15	3.360	1.003	41030.	41030.	108.9	2302.3	2411.2	108.9	2440.2	2549.1	0.3810	8.1569	8.5379
27	300.15	3.564	1.003	38810.	38810.	113.1	2299.5	2412.6	113.1	2437.8	2550.9	0.3949	8.1218	8.5168
28	301.15	3.778	1.004	36730.	36730.	117.3	2296.7	2414.0	117.3	2435.4	2552.7	0.4088	8.0870	8.4959
29	302.15	4.004	1.004	34770.	34770.	121.5	2293.8	2415.3	121.5	2433.1	2554.5	0.4227	8.0524	8.4751
30	303.15	4.241	1.004	32930.	32930.	125.7	2291.0	2416.7	125.7	2430.7	2556.4	0.4365	8.0180	8.4546
31	304.15	4.491	1.005	31200.	31200.	129.8	2288.2	2418.0	129.8	2428.3	2558.2	0.4503	7.9839	8.4342
32	305.15	4.753	1.005	29570.	29570.	134.0	2285.4	2419.4	134.0	2425.9	2560.0	0.4640	7.9500	8.4140
33	306.15	5.029	1.005	28040.	28040.	138.2	2282.6	2420.8	138.2	2423.6	2561.8	0.4777	7.9163	8.3939
34	307.15	5.318	1.006	26600.	26600.	142.4	2279.7	2422.1	142.4	2421.2	2563.6	0.4913	7.8828	8.3740
35	308.15	5.622	1.006	25240.	25240.	146.6	2276.9	2423.5	146.6	2418.8	2565.4	0.5049	7.8495	8.3543
36	309.15	5.940	1.006	23970.	23970.	150.7	2274.1	2424.8	150.7	2416.4	2567.2	0.5184	7.8164	8.3348
37	310.15	6.274	1.007	22760.	22760.	154.9	2271.3	2426.2	154.9	2414.1	2569.0	0.5319	7.7835	8.3154
38	311.15	6.624	1.007	21630.	21630.	159.1	2268.4	2427.5	159.1	2411.7	2570.8	0.5453	7.7509	8.2962
39	312.15	6.991	1.007	20560.	20560.	163.3	2265.6	2428.9	163.3	2409.3	2572.6	0.5588	7.7184	8.2772
40	313.15	7.375	1.008	19550.	19550.	167.4	2262.8	2430.2	167.5	2406.9	2574.4	0.5721	7.6861	8.2583
41	314.15	7.777	1.008	18590.	18590.	171.6	2259.9	2431.6	171.6	2404.5	2576.2	0.5854	7.6541	8.2395
42	315.15	8.198	1.009	17690.	17690.	175.8	2257.1	2432.9	175.8	2402.1	2577.9	0.5987	7.6222	8.2209
43	316.15	8.639	1.009	16840.	16840.	180.0	2254.3	2434.2	180.0	2399.7	2579.7	0.6120	7.5905	8.2025
44	317.15	9.100	1.009	16040.	16040.	184.2	2251.4	2435.6	184.2	2397.3	2581.5	0.6252	7.5590	8.1842
45	318.15	9.582	1.010	15280.	15280.	188.3	2248.6	2436.9	188.4	2394.9	2583.3	0.6383	7.5277	8.1661
46	319.15	10.09	1.010	14560.	14560.	192.5	2245.7	2438.3	192.5	2392.5	2585.1	0.6514	7.4966	8.1481
47	320.15	10.61	1.011	13880.	13880.	196.7	2242.9	2439.6	196.7	2390.1	2586.9	0.6645	7.4657	8.1302
48	321.15	11.16	1.011	13230.	13230.	200.9	2240.0	2440.9	200.9	2387.7	2588.6	0.6776	7.4350	8.1125
49	322.15	11.74	1.012	12620.	12620.	205.1	2237.2	2442.3	205.1	2385.3	2590.4	0.6906	7.4044	8.0950
50	323.15	12.34	1.012	12040.	12050.	209.2	2234.3	2443.6	209.3	2382.9	2592.2	0.7035	7.3741	8.0776
51	324.15	12.96	1.013	11500.	11500.	213.4	2231.5	2444.9	213.4	2380.5	2593.9	0.7164	7.3439	8.0603
52	325.15	13.61	1.013	10980.	10980.	217.6	2228.6	2446.2	217.6	2378.1	2595.7	0.7293	7.3138	8.0432
53	326.15	14.29	1.014	10490.	10490.	221.8	2225.8	2447.6	221.8	2375.7	2597.5	0.7422	7.2840	8.0262
54	327.15	15.00	1.014	10020.	10020.	226.0	2222.9	2448.9	226.0	2373.2	2599.2	0.7550	7.2543	8.0093
55	328.15	15.74	1.015	9577.9	9578.9	230.2	2220.0	2450.2	230.2	2370.8	2601.0	0.7677	7.2248	7.9925
56	329.15	16.51	1.015	9157.7	9158.7	234.3	2217.2	2451.5	234.4	2368.4	2602.7	0.7804	7.1955	7.9759
57	330.15	17.31	1.016	8758.7	8759.8	238.5	2214.3	2452.8	238.5	2365.9	2604.5	0.7931	7.1663	7.9595
58	331.15	18.15	1.016	8379.8	8380.8	242.7	2211.4	2454.1	242.7	2363.5	2606.2	0.8058	7.1373	7.9431
59	332.15	19.02	1.017	8019.7	8020.8	246.9	2208.6	2455.4	246.9	2361.1	2608.0	0.8184	7.1085	7.9269
60	333.15	19.92	1.017	7677.5	7678.5	251.1	2205.7	2456.8	251.1	2358.6	2609.7	0.8310	7.0798	7.9108
61	334.15	20.86	1.018	7352.1	7353.2	255.3	2202.8	2458.1	255.3	2356.2	2611.4	0.8435	7.0513	7.8948
62	335.15	21.84	1.018	7042.7	7043.7	259.4	2199.9	2459.4	259.5	2353.7	2613.2	0.8560	7.0230	7.8790
63	336.15	22.86	1.019	6748.2	6749.3	263.6	2197.0	2460.7	263.6	2351.3	2614.9	0.8685	6.9948	7.8633
64	337.15	23.91	1.019	6468.0	6469.0	267.8	2194.1	2462.0	267.8	2348.8	2616.6	0.8809	6.9667	7.8477
65	338.15	25.01	1.020	6201.3	6202.3	272.0	2191.2	2463.2	272.0	2346.3	2618.4	0.8933	6.9388	7.8322
66	339.15	26.15	1.020	5947.2	5948.2	276.2	2188.3	2464.5	276.2	2343.9	2620.1	0.9057	6.9111	7.8168
67	340.15	27.33	1.021	5705.2	5706.2	280.4	2185.4	2465.8	280.4	2341.4	2621.8	0.9180	6.8835	7.8015
68	341.15	28.56	1.022	5474.6	5475.6	284.6	2182.5	2467.1	284.6	2338.9	2623.5	0.9303	6.8561	7.7864
69	342.15	29.84	1.022	5254.8	5255.8	288.8	2179.6	2468.4	288.8	2336.4	2625.2	0.9426	6.8288	7.7714
70	343.15	31.16	1.023	5045.2	5046.3	292.9	2176.7	2469.7	293.0	2334.0	2626.9	0.9548	6.8017	7.7565
71	344.15	32.53	1.023	4845.4	4846.4	297.1	2173.8	2470.9	297.2	2331.5	2628.6	0.9670	6.7747	7.7417
72	345.15	33.96	1.024	4654.7	4655.7	301.3	2170.9	2472.2	301.4	2329.0	2630.3	0.9792	6.7478	7.7270
73	346.15	35.43	1.025	4472.7	4473.7	305.5	2168.0	2473.5	305.5	2326.5	2632.0	0.9913	6.7211	7.7124
74	347.15	36.96	1.025	4299.0	4300.0	309.7	2165.1	2474.8	309.7	2324.0	2633.7	1.0034	6.6945	7.6979

...5/-

DATA FOR QUESTION 4

Table F.1. Saturated Steam, SI Units

			SPECIFIC VOLUME V			INTERNAL ENERGY U			ENTHALPY H			ENTROPY S		
t °C	T K	P kPa	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.
75	348.15	38.55	1.026	4133.1	4134.1	313.9	2162.1	2476.0	313.9	2321.5	2635.4	1.0154	6.6681	7.6835
76	349.15	40.19	1.027	3974.6	3975.7	318.1	2159.2	2477.3	318.1	2318.9	2637.1	1.0275	6.6418	7.6693
77	350.15	41.89	1.027	3823.3	3824.3	322.3	2156.3	2478.5	322.3	2316.4	2638.7	1.0395	6.6156	7.6551
78	351.15	43.65	1.028	3678.6	3679.6	326.5	2153.3	2479.8	326.5	2313.9	2640.4	1.0514	6.5896	7.6410
79	352.15	45.47	1.029	3540.3	3541.3	330.7	2150.4	2481.1	330.7	2311.4	2642.1	1.0634	6.5637	7.6271
80	353.15	47.36	1.029	3408.1	3409.1	334.9	2147.4	2482.3	334.9	2308.8	2643.8	1.0753	6.5380	7.6132
81	354.15	49.31	1.030	3281.6	3282.6	339.1	2144.5	2483.5	339.1	2306.3	2645.4	1.0871	6.5123	7.5995
82	355.15	51.33	1.031	3160.6	3161.6	343.3	2141.5	2484.8	343.3	2303.8	2647.1	1.0990	6.4868	7.5858
83	356.15	53.42	1.031	3044.8	3045.8	347.5	2138.6	2486.0	347.5	2301.2	2648.7	1.1108	6.4615	7.5722
84	357.15	55.57	1.032	2933.9	2935.0	351.7	2135.6	2487.3	351.7	2298.6	2650.4	1.1225	6.4362	7.5587
85	358.15	57.80	1.033	2827.8	2828.8	355.9	2132.6	2488.5	355.9	2296.1	2652.0	1.1343	6.4111	7.5454
86	359.15	60.11	1.033	2726.1	2727.2	360.1	2129.7	2489.7	360.1	2293.5	2653.6	1.1460	6.3861	7.5321
87	360.15	62.49	1.034	2628.8	2629.8	364.3	2126.7	2490.9	364.3	2290.9	2655.3	1.1577	6.3612	7.5189
88	361.15	64.95	1.035	2535.4	2536.5	368.5	2123.7	2492.2	368.5	2288.4	2656.9	1.1693	6.3365	7.5058
89	362.15	67.49	1.035	2446.0	2447.0	372.7	2120.7	2493.4	372.7	2285.8	2658.5	1.1809	6.3119	7.4928
90	363.15	70.11	1.036	2360.3	2361.3	376.9	2117.7	2494.6	376.9	2283.2	2660.1	1.1925	6.2873	7.4799
91	364.15	72.81	1.037	2278.0	2279.1	381.1	2114.7	2495.8	381.1	2280.6	2661.7	1.2041	6.2629	7.4670
92	365.15	75.61	1.038	2199.2	2200.2	385.3	2111.7	2497.0	385.4	2278.0	2663.4	1.2156	6.2387	7.4543
93	366.15	78.49	1.038	2123.5	2124.5	389.5	2108.7	2498.2	389.6	2275.4	2665.0	1.2271	6.2145	7.4416
94	367.15	81.46	1.039	2050.9	2051.9	393.7	2105.7	2499.4	393.8	2272.8	2666.6	1.2386	6.1905	7.4291
95	368.15	84.53	1.040	1981.2	1982.2	397.9	2102.7	2500.6	398.0	2270.2	2668.1	1.2501	6.1665	7.4166
96	369.15	87.69	1.041	1914.3	1915.3	402.1	2099.7	2501.8	402.2	2267.5	2669.7	1.2615	6.1427	7.4042
97	370.15	90.94	1.041	1850.0	1851.0	406.3	2096.6	2503.0	406.4	2264.9	2671.3	1.2729	6.1190	7.3919
98	371.15	94.30	1.042	1788.3	1789.3	410.5	2093.6	2504.1	410.6	2262.2	2672.9	1.2842	6.0954	7.3796
99	372.15	97.76	1.043	1729.0	1730.0	414.7	2090.6	2505.3	414.8	2259.6	2674.4	1.2956	6.0719	7.3675
100	373.15	101.33	1.044	1672.0	1673.0	419.0	2087.5	2506.5	419.1	2256.9	2676.0	1.3069	6.0485	7.3554
102	375.15	108.78	1.045	1564.5	1565.5	427.4	2081.4	2508.8	427.5	2251.6	2679.1	1.3294	6.0021	7.3315
104	377.15	116.68	1.047	1465.1	1466.2	435.8	2075.3	2511.1	435.9	2246.3	2682.2	1.3518	5.9560	7.3078
106	379.15	125.04	1.049	1373.1	1374.2	444.3	2069.2	2513.4	444.4	2240.9	2685.3	1.3742	5.9104	7.2845
108	381.15	133.90	1.050	1287.9	1288.9	452.7	2063.0	2515.7	452.9	2235.4	2688.3	1.3964	5.8651	7.2615
110	383.15	143.27	1.052	1208.9	1209.9	461.2	2056.8	2518.0	461.3	2230.0	2691.3	1.4185	5.8203	7.2388
112	385.15	153.16	1.054	1135.6	1136.6	469.6	2050.6	2520.2	469.8	2224.5	2694.3	1.4405	5.7758	7.2164
114	387.15	163.62	1.055	1067.5	1068.5	478.1	2044.3	2522.4	478.3	2219.0	2697.2	1.4624	5.7318	7.1942
116	389.15	174.65	1.057	1004.2	1005.2	486.6	2038.1	2524.6	486.7	2213.4	2700.2	1.4842	5.6881	7.1723
118	391.15	186.28	1.059	945.3	946.3	495.0	2031.8	2526.8	495.2	2207.9	2703.1	1.5060	5.6447	7.1507
120	393.15	198.54	1.061	890.5	891.5	503.5	2025.4	2529.0	503.7	2202.2	2706.0	1.5276	5.6017	7.1293
122	395.15	211.45	1.062	839.4	840.5	512.0	2019.1	2531.1	512.2	2196.6	2708.8	1.5491	5.5590	7.1082
124	397.15	225.04	1.064	791.8	792.8	520.5	2012.7	2533.2	520.7	2190.9	2711.6	1.5706	5.5167	7.0873
126	399.15	239.33	1.066	747.3	748.4	529.0	2006.3	2535.3	529.2	2185.2	2714.4	1.5919	5.4747	7.0666
128	401.15	254.35	1.068	705.8	706.9	537.5	1999.9	2537.4	537.8	2179.4	2717.2	1.6132	5.4330	7.0462
130	403.15	270.13	1.070	667.1	668.1	546.0	1993.4	2539.4	546.3	2173.6	2719.9	1.6344	5.3917	7.0261
132	405.15	286.70	1.072	630.8	631.9	554.5	1986.9	2541.4	554.8	2167.8	2722.6	1.6555	5.3507	7.0061
134	407.15	304.07	1.074	596.9	598.0	563.1	1980.4	2543.4	563.4	2161.9	2725.3	1.6765	5.3099	6.9864
136	409.15	322.29	1.076	565.1	566.2	571.6	1973.8	2545.4	572.0	2155.9	2727.9	1.6974	5.2695	6.9669
138	411.15	341.38	1.078	535.3	536.4	580.2	1967.2	2547.4	580.5	2150.0	2730.5	1.7182	5.2293	6.9475
140	413.15	361.38	1.080	507.4	508.5	588.7	1960.6	2549.3	589.1	2144.0	2733.1	1.7390	5.1894	6.9284
142	415.15	382.31	1.082	481.2	482.3	597.3	1953.9	2551.2	597.7	2137.9	2735.6	1.7597	5.1499	6.9095
144	417.15	404.20	1.084	456.6	457.7	605.9	1947.2	2553.1	606.3	2131.8	2738.1	1.7803	5.1105	6.8908
146	419.15	427.09	1.086	433.5	434.6	614.4	1940.5	2554.9	614.9	2125.7	2740.6	1.8008	5.0715	6.8723
148	421.15	451.01	1.089	411.8	412.9	623.0	1933.7	2556.8	623.5	2119.5	2743.0	1.8213	5.0327	6.8539
150	423.15	476.00	1.091	391.4	392.4	631.6	1926.9	2558.6	632.1	2113.2	2745.4	1.8416	4.9941	6.8358
152	425.15	502.08	1.093	372.1	373.2	640.2	1920.1	2560.3	640.8	2106.9	2747.7	1.8619	4.9558	6.8178
154	427.15	529.29	1.095	354.0	355.1	648.9	1913.2	2562.1	649.4	2100.6	2750.0	1.8822	4.9178	6.8000
156	429.15	557.67	1.098	336.9	338.0	657.5	1906.3	2563.8	658.1	2094.2	2752.3	1.9023	4.8800	6.7823
158	431.15	587.25	1.100	320.8	321.9	666.1	1899.3	2565.5	666.8	2087.7	2754.5	1.9224	4.8424	6.7648
160	433.15	618.06	1.102	305.7	306.8	674.8	1892.3	2567.1	675.5	2081.3	2756.7	1.9425	4.8050	6.7475
162	435.15	650.16	1.105	291.3	292.4	683.5	1885.3	2568.8	684.2	2074.7	2758.9	1.9624	4.7679	6.7303
164	437.15	683.56	1.107	277.8	278.9	692.1	1878.2	2570.4	692.9	2068.1	2761.0	1.9823	4.7309	6.7133
166	439.15	718.31	1.109	265.0	266.1	700.8	1871.1	2571.9	701.6	2061.4	2763.1	2.0022	4.6942	6.6964
168	441.15	754.45	1.112	252.9	254.0	709.5	1863.9	2573.4	710.4	2054.7	2765.1	2.0219	4.6577	6.6796
170	443.15	792.02	1.114	241.4	242.6	718.2	1856.7	2574.9	719.1	2047.9	2767.1	2.0416	4.6214	6.6630
172	445.15	831.06	1.117	230.6	231.7	727.0	1849.5	2576.4	727.9	2041.1	2769.0	2.0613	4.5853	6.6465
174	447.15	871.60	1.120	220.3	221.5	735.7	1842.2	2577.8	736.7	2034.2	2770.9	2.0809	4.5493	6.6302
176	449.15	913.68	1.122	210.6	211.7	744.4	1834.8	2579.3	745.5	2027.3	2772.7	2.1004	4.5136	6.6140
178	451.15	957.36	1.125	201.4	202.5	753.2	1827.4	2580.6	754.3	2020.2	2774.5	2.1199	4.4780	6.5979
180	453.15	1002.7	1.128	192.7	193.8	762.0	1820.0	2581.9	763.1	2013.1	2776.3	2.1393	4.4426	6.5819
182	455.15	1049.6	1.130	184.4	185.5	770.8	1812.5	2583.2	772.0	2006.0	2778.0	2.1587	4.4074	6.5660
184	457.15	1098.3	1.133	176.5	177.6	779.6	1804.9	2584.5	780.8	1998.8	2779.6	2.1780	4.3723	6.5503
186	459.15	1148.8	1.136	169.0	170.2	788.4	1797.3	2585.7	789.7	1991.5	2781.2	2.1972	4.3374	6.5346
188	461.15	1201.0	1.139	161.9	163.1	797.2	1789.7	2586.9	798.6	1984.2	2782.8	2.2164	4.3026	6.5191
190	463.15	1255.1	1.142	155.2	156.3	806.1	1782.0	2588.1	807.5	1976.7	2784.3	2.2356	4.2680	6.5036
192	465.15	1311.1	1.144	148.8	149.9	814.9	1774.2	2589.2	816.5	1969.3	2785.7	2.2547	4.2336	6.4883
194	467.15	1369.0	1.147	142.6	143.8	823.8	1766.4	2590.2	825.4	1961.7	2787.1	2.2738	4.1993	6.4730
196	469.15	1428.9	1.150	136.8	138.0	832.7	1758.6	2591.3	834.4	1954.1	2788.4	2.2928	4.1651	6.4578
198	471.15	1490.9	1.153	131.3	132.4	841.6	1750.6	2592.3	843.4	1946.4	2789.7	2.3117	4.1310	6.4428
200	473.15	1554.9	1.156	126.0	127.2	850.6	1742.6	2593.2	852.4	1938.6	2790.9	2.3307	4.0971	6.4278
202	475.15	1621.0	1.160	121.0	122.1	859.5	1734.6	2594.1	861.4	1930.7	2792.1	2.3495	4.0633	6.4128
204	477.15	1689.3	1.163	116.2	117.3	868.5	1726.5	2595.0	870.5	1922.8	2793.2	2.3684	4.0296	6.3980
206	479.15	1759.8	1.166	111.6	112.8	877.5	1718.3	2595.8	879.5	1914.7	2794.3	2.3872	3.9961	6.3832
208	481.15	1832.6	1.169	107.2	108.4	886.5	1710.1	2596.6	888.6	1906.6	2795.3	2.4059	3.9626	6.3686
210	483.15	1907.7	1.173	103.1	104.2	895.5	1701.8	2597.3	897.7	1898.5	2796.2	2.4247	3.9293	6.3539
212	485.15	1985.2	1.176	99.09	100.26	904.5	1693.5	2598.0	906.9	1890.2	2797.1	2.4434	3.8960	6.3394
214	487.15	2065.1	1.179	95.28	96.46	913.6	1685.1	2598.7	916.0	1881.8	2797.9	2.4620	3.8629	6.3249
216	489.15	2147.5	1.183	91.65	92.83	922.7	1676.6	2599.3	925.2	1873.4	2798.6	2.4806	3.8298	6.3104
218	491.15	2232.4	1.186	88.17	89.36	931.8	1668.0	2599.8	934.4	1864.9	2799.3	2.4992	3.7968	6.2960

...6/-

TABLE FOR QUESTION 5

The Lee/Kesler Generalized-correlation Tables

Values of ϕ^1

$P_r =$	0.0100	0.0500	0.1000	0.2000	0.4000	0.6000	0.8000	1.0000
T_r								
0.30	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.35	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.40	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.45	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
0.50	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0013	0.0013
0.55	0.9705	0.0069	0.0068	0.0068	0.0066	0.0065	0.0064	0.0063
0.60	0.9795	0.0227	0.0226	0.0223	0.0220	0.0216	0.0213	0.0210
0.65	0.9863	0.9311	0.0572	0.0568	0.0559	0.0551	0.0543	0.0535
0.70	0.9908	0.9528	0.9036	0.1182	0.1163	0.1147	0.1131	0.1116
0.75	0.9931	0.9683	0.9332	0.2112	0.2078	0.2050	0.2022	0.1994
0.80	0.9954	0.9772	0.9550	0.9057	0.3302	0.3257	0.3212	0.3168
0.85	0.9977	0.9863	0.9705	0.9375	0.4774	0.4708	0.4654	0.4590
0.90	0.9977	0.9908	0.9795	0.9594	0.9141	0.6323	0.6250	0.6165
0.93	0.9977	0.9931	0.9840	0.9705	0.9354	0.8953	0.7227	0.7144
0.95	0.9977	0.9931	0.9885	0.9750	0.9484	0.9183	0.7888	0.7797
0.97	1.0000	0.9954	0.9908	0.9795	0.9594	0.9354	0.9078	0.8413
0.98	1.0000	0.9954	0.9908	0.9817	0.9638	0.9440	0.9225	0.8729
0.99	1.0000	0.9954	0.9931	0.9840	0.9683	0.9528	0.9332	0.9036
1.00	1.0000	0.9977	0.9931	0.9863	0.9727	0.9594	0.9440	0.9311
1.01	1.0000	0.9977	0.9931	0.9885	0.9772	0.9638	0.9528	0.9462
1.02	1.0000	0.9977	0.9954	0.9908	0.9795	0.9705	0.9616	0.9572
1.05	1.0000	0.9977	0.9977	0.9954	0.9885	0.9863	0.9840	0.9840
1.10	1.0000	1.0000	1.0000	1.0000	1.0023	1.0046	1.0093	1.0163
1.15	1.0000	1.0000	1.0023	1.0046	1.0116	1.0186	1.0257	1.0375
1.20	1.0000	1.0023	1.0046	1.0069	1.0163	1.0280	1.0399	1.0544
1.30	1.0000	1.0023	1.0069	1.0116	1.0257	1.0399	1.0544	1.0716
1.40	1.0000	1.0046	1.0069	1.0139	1.0304	1.0471	1.0642	1.0815
1.50	1.0000	1.0046	1.0069	1.0163	1.0328	1.0496	1.0666	1.0865
1.60	1.0000	1.0046	1.0069	1.0163	1.0328	1.0496	1.0691	1.0865
1.70	1.0000	1.0046	1.0093	1.0163	1.0328	1.0496	1.0691	1.0865
1.80	1.0000	1.0046	1.0069	1.0163	1.0328	1.0496	1.0666	1.0840
1.90	1.0000	1.0046	1.0069	1.0163	1.0328	1.0496	1.0666	1.0815
2.00	1.0000	1.0046	1.0069	1.0163	1.0304	1.0471	1.0642	1.0815
2.20	1.0000	1.0046	1.0069	1.0139	1.0304	1.0447	1.0593	1.0765
2.40	1.0000	1.0046	1.0069	1.0139	1.0280	1.0423	1.0568	1.0716
2.60	1.0000	1.0023	1.0069	1.0139	1.0257	1.0399	1.0544	1.0666
2.80	1.0000	1.0023	1.0069	1.0116	1.0257	1.0375	1.0496	1.0642
3.00	1.0000	1.0023	1.0069	1.0116	1.0233	1.0352	1.0471	1.0593
3.50	1.0000	1.0023	1.0046	1.0023	1.0209	1.0304	1.0423	1.0520
4.00	1.0000	1.0023	1.0046	1.0093	1.0186	1.0280	1.0375	1.0471

Values of ϕ^0

$P_r =$	0.0100	0.0500	0.1000	0.2000	0.4000	0.6000	0.8000	1.0000
T_r								
0.30	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.35	0.0034	0.0007	0.0003	0.0002	0.0001	0.0001	0.0001	0.0000
0.40	0.0272	0.0055	0.0028	0.0014	0.0007	0.0005	0.0004	0.0003
0.45	0.1321	0.0266	0.0135	0.0069	0.0036	0.0025	0.0020	0.0016
0.50	0.4529	0.0912	0.0461	0.0235	0.0122	0.0085	0.0067	0.0055
0.55	0.9817	0.2432	0.1227	0.0625	0.0325	0.0225	0.0176	0.0146
0.60	0.9840	0.5383	0.2716	0.1384	0.0718	0.0497	0.0386	0.0321
0.65	0.9886	0.9419	0.5212	0.2655	0.1374	0.0948	0.0738	0.0611
0.70	0.9908	0.9528	0.9057	0.4560	0.2360	0.1626	0.1262	0.1045
0.75	0.9931	0.9616	0.9226	0.7178	0.3715	0.2559	0.1982	0.1641
0.80	0.9931	0.9683	0.9354	0.8730	0.5445	0.3750	0.2904	0.2404
0.85	0.9954	0.9727	0.9462	0.8933	0.7534	0.5188	0.4018	0.3319
0.90	0.9954	0.9772	0.9550	0.9099	0.8204	0.6823	0.5297	0.4375
0.93	0.9954	0.9795	0.9594	0.9183	0.8375	0.7551	0.6109	0.5058
0.95	0.9954	0.9817	0.9616	0.9226	0.8472	0.7709	0.6668	0.5521
0.97	0.9954	0.9817	0.9638	0.9268	0.8570	0.7852	0.7112	0.5984
0.98	0.9954	0.9817	0.9638	0.9290	0.8610	0.7925	0.7211	0.6223
0.99	0.9977	0.9840	0.9661	0.9311	0.8650	0.7980	0.7295	0.6442
1.00	0.9977	0.9840	0.9661	0.9333	0.8690	0.8035	0.7379	0.6668
1.01	0.9977	0.9840	0.9683	0.9354	0.8730	0.8110	0.7464	0.6792
1.02	0.9977	0.9840	0.9683	0.9376	0.8770	0.8166	0.7551	0.6902
1.05	0.9977	0.9863	0.9705	0.9441	0.8872	0.8318	0.7762	0.7194
1.10	0.9977	0.9886	0.9750	0.9506	0.9016	0.8531	0.8072	0.7586
1.15	0.9977	0.9886	0.9795	0.9572	0.9141	0.8730	0.8318	0.7907
1.20	0.9977	0.9908	0.9817	0.9616	0.9247	0.8892	0.8531	0.8166
1.30	0.9977	0.9931	0.9863	0.9705	0.9419	0.9141	0.8872	0.8590
1.40	0.9977	0.9931	0.9886	0.9772	0.9550	0.9333	0.9120	0.8892
1.50	1.0000	0.9954	0.9908	0.9817	0.9638	0.9462	0.9290	0.9141
1.60	1.0000	0.9954	0.9931	0.9863	0.9727	0.9572	0.9441	0.9311
1.70	1.0000	0.9977	0.9954	0.9886	0.9772	0.9661	0.9550	0.9462
1.80	1.0000	0.9977	0.9954	0.9908	0.9817	0.9727	0.9661	0.9572
1.90	1.0000	0.9977	0.9954	0.9931	0.9863	0.9795	0.9727	0.9661
2.00	1.0000	0.9977	0.9977	0.9954	0.9886	0.9840	0.9795	0.9727
2.20	1.0000	1.0000	0.9977	0.9977	0.9931	0.9908	0.9886	0.9840
2.40	1.0000	1.0000	1.0000	0.9977	0.9977	0.9954	0.9931	0.9931
2.60	1.0000	1.0000	1.0000	1.0000	1.0000	0.9977	0.9977	0.9977
2.80	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0023	1.0023
3.00	1.0000	1.0000	1.0000	1.0000	1.0023	1.0023	1.0046	1.0046
3.50	1.0000	1.0000	1.0000	1.0023	1.0023	1.0046	1.0069	1.0093
4.00	1.0000	1.0000	1.0000	1.0023	1.0046	1.0069	1.0093	1.0116

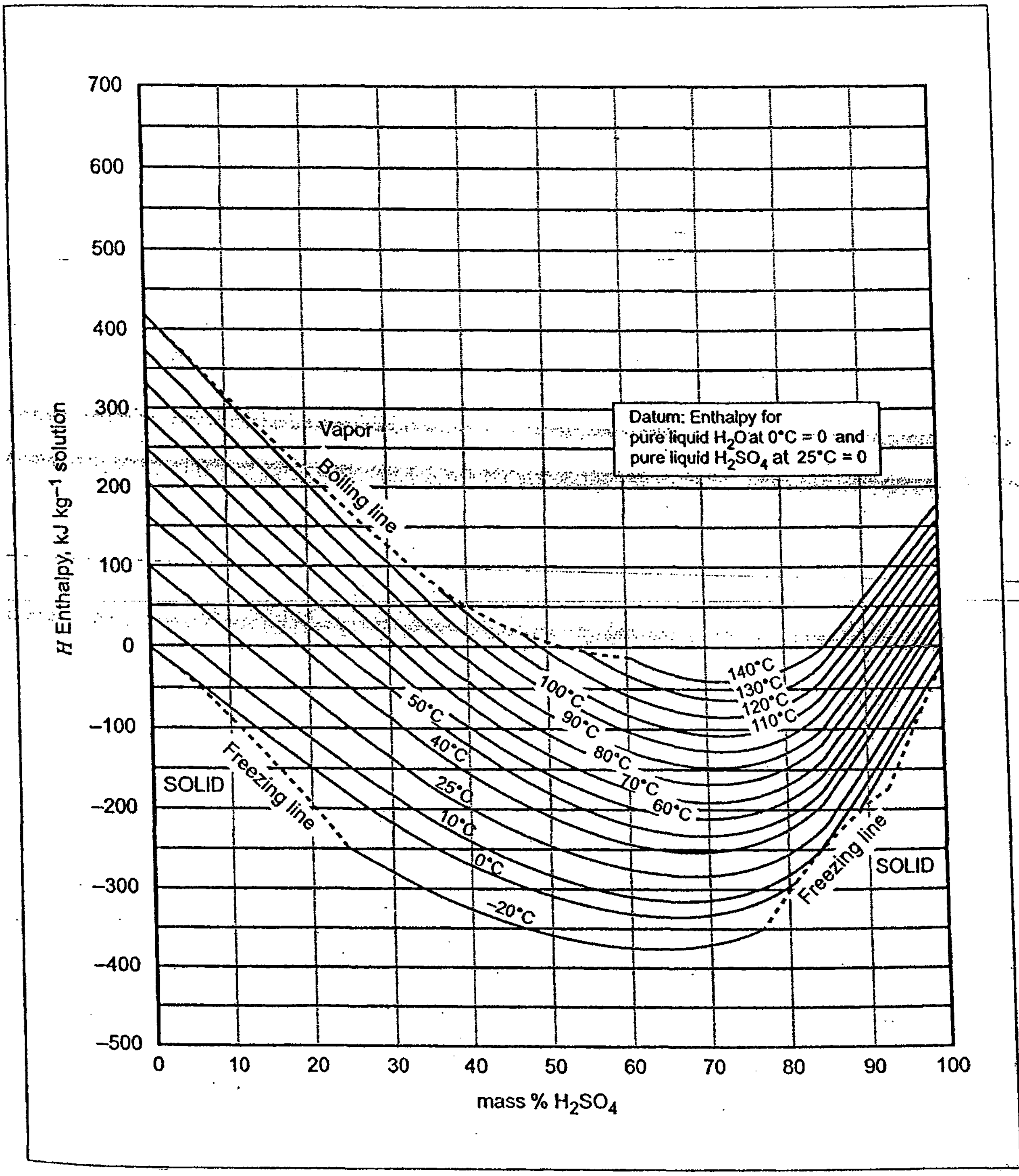


Figure Q.5 *Hx* diagram for H_2SO_4/H_2O (Redrawn from data of *Technical Note* 270-3, National Bureau of Standards, USA, 1968; T. R. Bump and W. L. Sibbitt, *Ind. Eng. Chem.*, vol. 47, pp. 1665-1670, 1955; and C. M. Gable, H. F. Betz and S. H. Maron, *J. of Am. Chem. Soc.*, vol. 72, pp. 1445–1448, 1950. By permissions.)

...8/-

Table 6 [a] [i]

Thermodynamic Properties of R-134a

Saturated R-134a

Temp. (°C)	Press. (kPa)	SPECIFIC VOLUME, m³/kg Sat. Liquid v_f	Evap. v_{fg}	Sat. Vapor v_g	INTERNAL ENERGY, kJ/kg Sat. Liquid u_f	Evap. u_{fg}	Sat. Vapor u_g
−70	8.3	0.000675	1.97207	1.97274	119.46	218.74	338.20
−65	11.7	0.000679	1.42915	1.42983	123.18	217.76	340.94
−60	16.3	0.000684	1.05199	1.05268	127.52	216.19	343.71
−55	22.2	0.000689	0.78609	0.78678	132.36	214.14	346.50
−50	29.9	0.000695	0.59587	0.59657	137.60	211.71	349.31
−45	39.6	0.000701	0.45783	0.45853	143.15	208.99	352.15
−40	51.8	0.000708	0.35625	0.35696	148.95	206.05	355.00
−35	66.8	0.000715	0.28051	0.28122	154.93	202.93	357.86
−30	85.1	0.000722	0.22330	0.22402	161.06	199.67	360.73
−26.3	101.3	0.000728	0.18947	0.19020	165.73	197.16	362.89
−25	107.2	0.000730	0.17957	0.18030	167.30	196.31	363.61
−20	133.7	0.000738	0.14576	0.14649	173.65	192.85	366.50
−15	165.0	0.000746	0.11932	0.12007	180.07	189.32	369.39
−10	201.7	0.000755	0.09845	0.09921	186.57	185.70	372.27
−5	244.5	0.000764	0.08181	0.08257	193.14	182.01	375.15
0	294.0	0.000773	0.06842	0.06919	199.77	178.24	378.01
5	350.9	0.000783	0.05755	0.05833	206.48	174.38	380.85
10	415.8	0.000794	0.04866	0.04945	213.25	170.42	383.67
15	489.5	0.000805	0.04133	0.04213	220.10	166.35	386.45
20	572.8	0.000817	0.03524	0.03606	227.03	162.16	389.19
25	666.3	0.000829	0.03015	0.03098	234.04	157.83	391.87
30	771.0	0.000843	0.02587	0.02671	241.14	153.34	394.48
35	887.6	0.000857	0.02224	0.02310	248.34	148.68	397.02
40	1017.0	0.000873	0.01915	0.02002	255.65	143.81	399.46
45	1160.2	0.000890	0.01650	0.01739	263.08	138.71	401.79
50	1318.1	0.000908	0.01422	0.01512	270.63	133.35	403.98
55	1491.6	0.000928	0.01224	0.01316	278.33	127.68	406.01
60	1681.8	0.000951	0.01051	0.01146	286.19	121.66	407.85
65	1889.9	0.000976	0.00899	0.00997	294.24	115.22	409.46
70	2117.0	0.001005	0.00765	0.00866	302.51	108.27	410.78
75	2364.4	0.001038	0.00645	0.00749	311.06	100.68	411.74
80	2633.6	0.001078	0.00537	0.00645	319.96	92.26	412.22
85	2926.2	0.001128	0.00437	0.00550	329.35	82.67	412.01
90	3244.5	0.001195	0.00341	0.00461	339.51	71.24	410.75
95	3591.5	0.001297	0.00243	0.00373	351.17	56.25	407.42
100	3973.2	0.001557	0.00108	0.00264	368.55	28.19	396.74
101.2	4064.0	0.001969	0	0.00197	382.97	0	382.97

...9/-

Table 6 [a] [ii]

Superheated R-134a

Temp. (°C)	v (m³/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg-K)	v (m³/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg-K)
	800 kPa (31.30)				1000 kPa (39.37)			
Sat.	0.02571	395.15	415.72	1.7150	0.02038	399.16	419.54	1.7125
40	0.02711	403.17	424.86	1.7446	0.02047	399.78	420.25	1.7148
50	0.02861	412.23	435.11	1.7768	0.02185	409.39	431.24	1.7494
60	0.03002	421.20	445.22	1.8076	0.02311	418.78	441.89	1.7818
70	0.03137	430.17	455.27	1.8373	0.02429	428.05	452.34	1.8127
80	0.03268	439.17	465.31	1.8662	0.02542	437.29	462.70	1.8425
90	0.03394	448.22	475.38	1.8943	0.02650	446.53	473.03	1.8713
100	0.03518	457.35	485.50	1.9218	0.02754	455.82	483.36	1.8994
110	0.03639	466.58	495.70	1.9487	0.02856	465.18	493.74	1.9268
120	0.03758	475.92	505.99	1.9753	0.02956	474.62	504.17	1.9537
130	0.03876	485.37	516.38	2.0014	0.03053	484.16	514.69	1.9801
140	0.03992	494.94	526.88	2.0271	0.03150	493.81	525.30	2.0061
150	0.04107	504.64	537.50	2.0525	0.03244	503.57	536.02	2.0318
160	0.04221	514.46	548.23	2.0775	0.03338	513.46	546.84	2.0570
170	0.04334	524.42	559.09	2.1023	0.03431	523.46	557.77	2.0820
180	0.04446	534.51	570.08	2.1268	0.03523	533.60	568.83	2.1067
	1200 kPa (46.31)				1400 kPa (52.42)			
Sat.	0.01676	402.37	422.49	1.7102	0.01414	404.98	424.78	1.7077
50	0.01724	406.15	426.84	1.7237	—	—	—	—
60	0.01844	416.08	438.21	1.7584	0.01503	413.03	434.08	1.7360
70	0.01953	425.74	449.18	1.7908	0.01608	423.20	445.72	1.7704
80	0.02055	435.27	459.92	1.8217	0.01704	433.09	456.94	1.8026
90	0.02151	444.74	470.55	1.8514	0.01793	442.83	467.93	1.8333
100	0.02244	454.20	481.13	1.8801	0.01878	452.50	478.79	1.8628
110	0.02333	463.71	491.70	1.9081	0.01958	462.17	489.59	1.8914
120	0.02420	473.27	502.31	1.9354	0.02036	471.87	500.38	1.9192
130	0.02504	482.91	512.97	1.9621	0.02112	481.63	511.19	1.9463
140	0.02587	492.65	523.70	1.9884	0.02186	491.46	522.05	1.9730
150	0.02669	502.48	534.51	2.0143	0.02258	501.37	532.98	1.9991
160	0.02750	512.43	545.43	2.0398	0.02329	511.39	543.99	2.0248
170	0.02829	522.50	556.44	2.0649	0.02399	521.51	555.10	2.0502
180	0.02907	532.68	567.57	2.0898	0.02468	531.75	566.30	2.0752