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Exam 2
C&PE 211
Monday October 29, 2012
Closed Book - Closed Notes

Name:

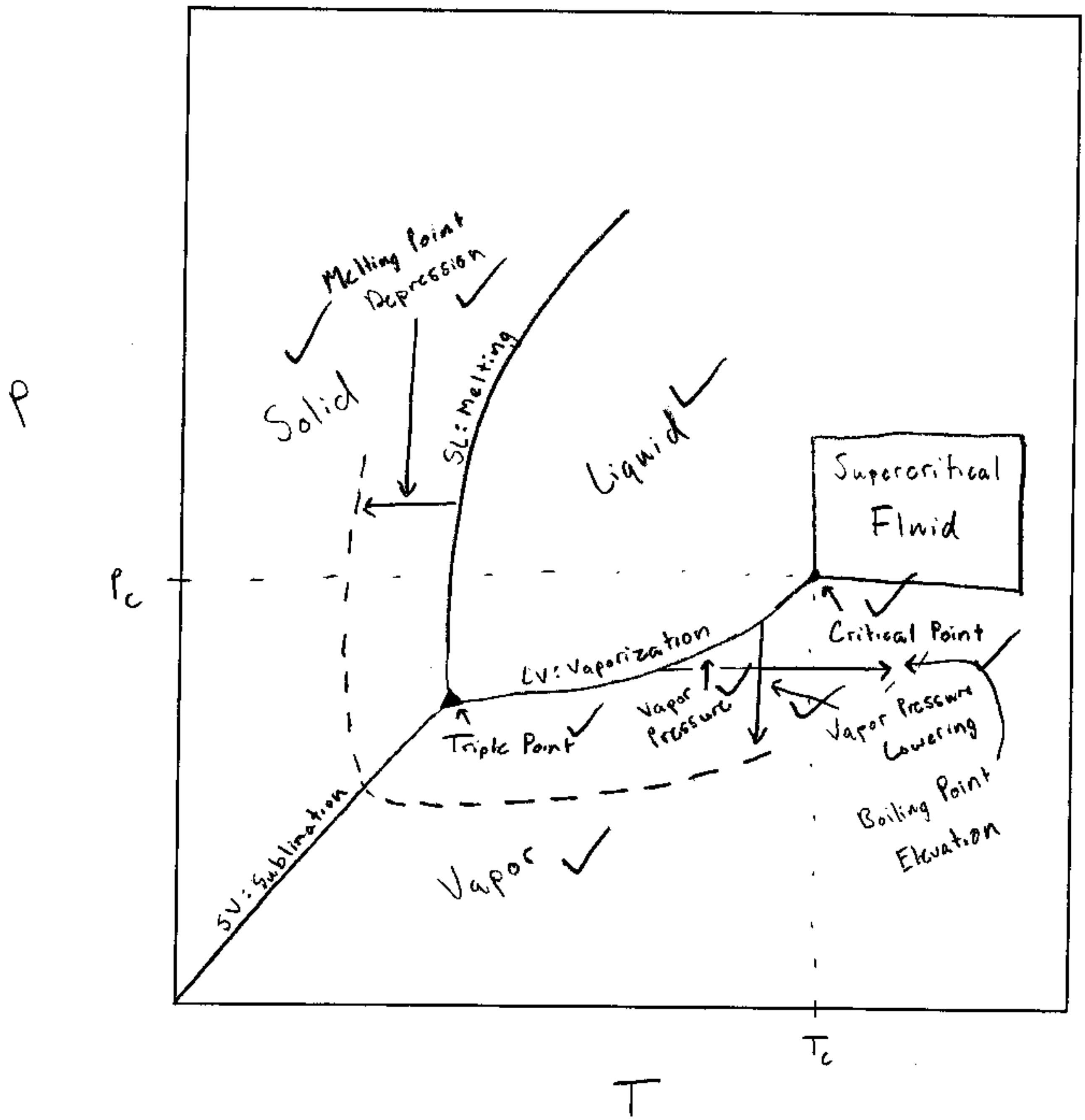
1. Please do not turn the page until you are instructed to do so.
2. Please write your name in the space provided and if you separate the pages, put your initials on all of the pages.
3. Please read each question carefully and work those that you know first. Do not spend too much time on one problem. If you get stuck move on to the next question. Partial credit is given so working through a problem as much as you can is to your benefit.
4. Do all of the work on the sheets provided. Write clearly and organized. If I cannot read your writing or follow the solution, no credit will be given.
5. Only a small amount of credit is given for the answer to the problem. The majority of the credit is given for the formulas and the work you use to solve the problem. If you do not show all of your work you will not receive full credit for the problem.
6. Cheating on this exam will result in a no credit for the exam. Two instances of cheating will result in failure of the course.
7. If a box is provided please put your answers in the box. If a box is not provided, please box your final answers. All work will be checked, but the answer in the box will be considered to be the final answer.

Please remember:
Don't panic! Panicking can cause silly errors.
Good Luck!

"So, Foster! That's how you want it, huh? ...
Then take this!"

2. (11 points total, no partial credit for each part)
In the space below, show an example of a typical pure solvent phase diagram with **temperature on the x axis** and **pressure on the y axis**.

a. (3 points) Identify the regions of solid, vapor, and liquid.
b. (2 points) Identify the critical point and triple point
c. (2 points) Identify which line corresponds to the vapor pressure
d. (2 points) Using the same graph, show what happens to the phase-equilibrium curves when you have a solution. Use a dashed line to indicate the solution phase-equilibrium line.
e. (2 points) Using the graph show the colligative properties of vapor pressure lowering, boiling point elevation, and melting point depression.



3. (3 points – no partial credit) Explain what an extensive variable is and give three specific examples.

3 ✓

Extensive Variables depend on the size of the system and the amount of material.

Volume, Mass, Moles ✓

4. (5 points – no partial credit for each part)

a. (3 points) If you have a mixture of ice, liquid water, and water vapor use the Gibbs phase rule to show how many degrees of freedom exist for that system.

5 ✓

b. (2 points) Explain why this answer makes sense or what is significant about the answer.

a. $D.o.F = C - P + 2$

$= 1 - 3 + 2$ ✓

$= 0$

b. For ice, liquid water, and water vapor to exist together you must be at the triple point on a phase diagram, which has a unique temperature and pressure. ✓

5. (20 points) An air stream containing 10% water vapor is being cooled isobarically at 1 atm. If the dew point temperature is found to be 53°C and you know the stream has 22°C of superheat.

20/

a. Determine the temperature of the stream entering the unit and the relative humidity of the stream entering the unit.
b. If the mole fraction of the water in the vapor leaving the condenser is 0.04, find the operating temperature of the condenser.

Temperature of feed = 75 °C ✓
Relative humidity of feed = .26
Operating temperature of the condenser = 29.2 °C

$T_{Feed} = 53 + 22 = 75\ °C$

Relative Humidity = p_i / p^*

$p^*(75°C) = 289.1$ mmHg (Table B.3)

$p_i = .1(760) = 76$ mmHg

$76/289.1 = .26$

$y_i P = x_i p^*$

$.04(760) = 30.4 = p^*(T)$

$T = 29.2°C$ (Table B.3)

25

6. (25 points) A process stream flowing at 35kmol/h contains 15 mole% hydrogen and the remainder 1-butene. The stream pressure is 10 atm absolute, the temperature is 50°C and the velocity of the fluid is 150 m/min.

a. Determine the diameter (in cm) of the pipe transporting the fluid in the process assuming that 10 atm is too high of a pressure to be considered ideal. ✓

b. Would be the diameter of the pipe but larger, smaller, or the same if you had assumed the gas was ideal and why? You do not need to do the calculations but you must justify your answer. ✓

a. Diameter of the pipe (cm) = 10.7 cm ✓

b. Larger, the volume of the ideal gas would be greater, therefore the diameter of the pipe would need to be larger. ✓

$35000\ \text{mol/hr} \times 1\ \text{hr}/60\ \text{min} = 583.33\ \text{mol/min}$

$.15\ H_2$

$.85$ 1-butene

$PV = znRT$

$P = 10$ atm

$T = 50°C + 273.15 = 323.15\ K$

$150\ \text{m/min}$

V in L

$R = .08206$

$\frac{1.35}{150} = .009\ m^2 = \pi r^2$

$r = .0535\ m \therefore d = .107\ m \times 100\ \text{cm}/1\ \text{m}$
$= 10.7\ \text{cm}$

$(10)(V) = (.87)(583.33)(.08206)(323.15)$

$V = 1345.77\ \text{L/min} \times 1\ m^3/1000\ L$
$= 1.35\ m^3/\text{min}$ ✓

$T_R = T/T_c = 323.15/362.855 = .89$

$P_R = P/P_c = 10/36.865 = .27$

$z = .87$ (Table 5.4) ✓

$T_c' = \Sigma y_i T_{c_i} = (.15)(33.3 + 8) + (.85)(419.6) = 362.855\ K$

$P_c' = \Sigma y_i P_{c_i} = (.15)(12.8 + 8) + (.85)(39.7) = 36.865\ K$

Newton's correction

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7. (25 points) A mixture of 40% isobutane and 60% n-pentane is sent to a flash unit where a liquid and a vapor stream are produced. The unit is operating at 49°C and the streams leaving the unit can be considered to be in equilibrium. If the liquid stream leaving the flash unit is 25 mole% isobutane, find the pressure of the flash unit, the composition of the vapor stream leaving the unit, and the total vapor to liquid ratio (V/L).

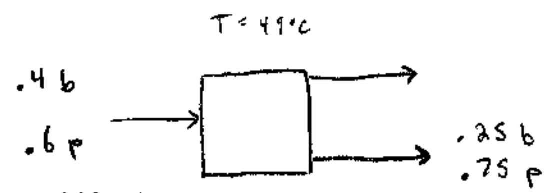
Pressure of flash unit (mm of Hg) = 2111.15 mmHg √

Composition of vapor stream leaving flash: √
isobutane (mole %) = 59 mole%
n-pentane (mole %) = 41 mole%

Total vapor to liquid ratio (V/L) = .79 √

$y_i P = x_i P^*$

$y_i = \frac{x_i P^*}{P}$



Butane $P^*(49°C) = 10^{\wedge} 6.78866 - 899.617 / 241.942 + 49 = 4972.52$ mmHg

Pentane $P^*(49°C) = 10^{\wedge} 6.84471 - 1060.793 / 231.541 + 49 = 1157.36$ mmHg

$$\frac{(.25)(4972.52)}{P} + \frac{(.75)(1157.36)}{P} = 1 = 2111.15 / P$$

$P = 2111.15$ mmHg

Butane: $y_i = \frac{(.25)(4972.52)}{2111.15} = .59$

Pentane: $y_i = 1 - .59 = .41$

Butane:

$z_i - x_i = (V/L)(y_i - z_i)$

$.4 - .25 = (V/L)(.59 - .4)$

$V/L = .79$

$F = V + L$

$z_i F = y_i V + x_i L$

$\therefore z_i (V + L) = y_i V + x_i L$

$z_i V + z_i L = y_i V + x_i L$

$z_i (V/L) + z_i = y_i (V/L) + x_i$

Extra credit (5 points – no partial credit)

The following is a ternary diagram of the liquid-liquid equilibrium for acetone (A), water (W) and methyl-isobutyl-ketone (MIK) at 25 °C and 1 atm in mass fraction (W_i).

5

a) Draw a point with a circle around it to indicate where on the ternary diagram you would be if you made a mixture in the proportions of 30% acetone, 43 % water and 27% MIK.

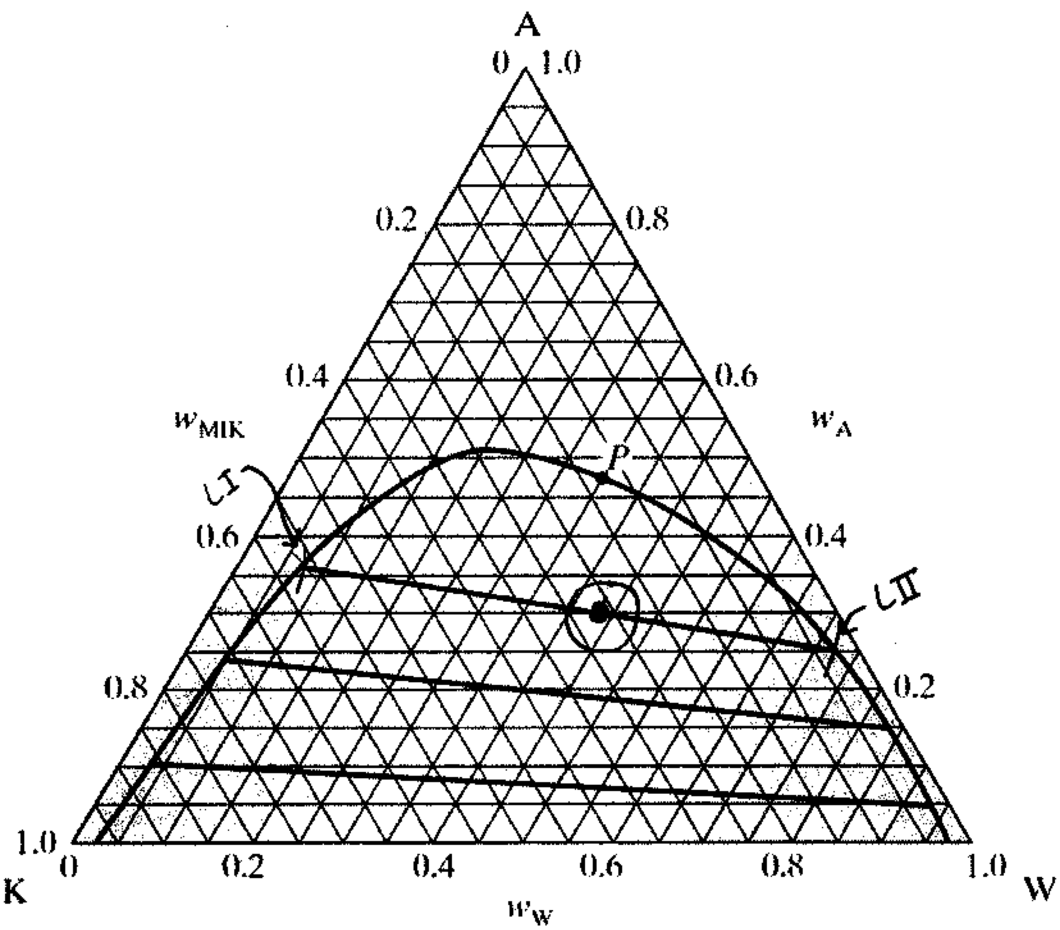
b) IF you let the mixture sit and come to equilibrium, determine if you would have 1 phase or 2 phases for the mixture above and if you had two phases determine the composition of each phase.

How many phases? 2

If more than one phase, what is composition of each phase?

LI: 36% acetone, 7% water, 57% MIK

LII: 25% acetone, 72% water, 3% MIK ✓



Information for Exam 2

			Antoine's Coefficients		
Compound	T_C (K)	P_C (atm)	**A**	**B**	**C**
Isobutane	408.1	36.0	6.78866	899.617	241.942
n-pentane	469.80	33.3	6.84471	1060.793	231.541
1-butene	419.6	39.7	6.53101	810.261	228.066
Water (60 - 150 C)	647.4	218.3	7.96681	1668.210	228.000
Water (0 – 60 C)	647.4	218.3	8.10765	1750.286	235.000
Hydrogen	33.3	12.8			

R = 8.314 m^3 *Pa/(mol*K)

R = 0.08314 L*bar/(mol*K)

R = 0.08206 L*atm/(mol*K)

1000L = $1m^3$ = 10^6 cm^3 = 10^6 mL

1 atm = 760 mm hg = 1.101325 bar = 1.10325 x 10^5 Pa

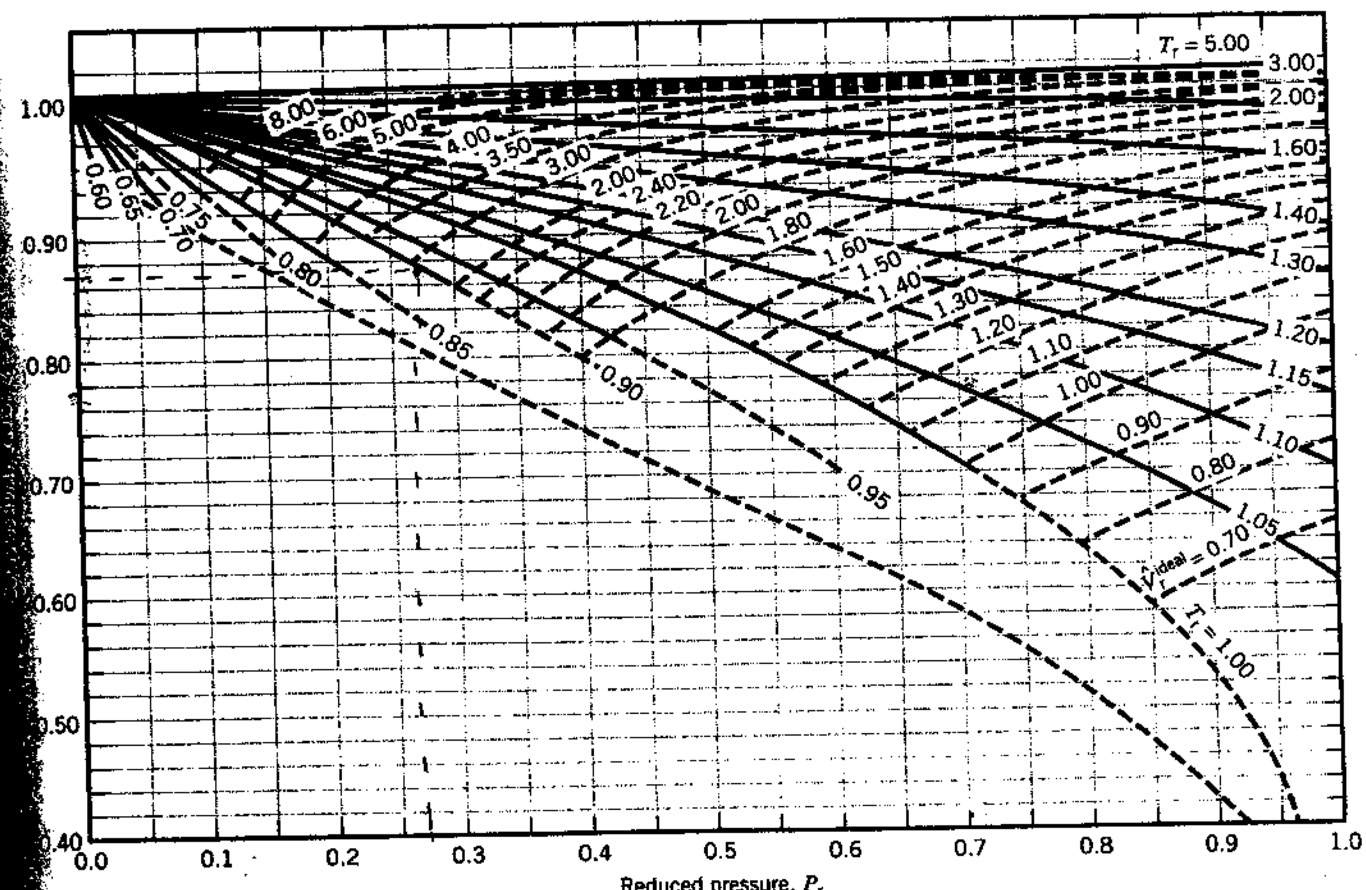

$T_r = 5.00$
3.00
2.00
1.60
1.40
1.30
1.20
1.15
1.10
1.05
8.00
6.00
5.00
4.00
3.50
3.00
2.00
2.40
2.20
2.00
1.80
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
$\hat{V}_r^{ideal} = 0.70$
$T_r = 1.00$
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Reduced pressure, P_r

Table B.3 Vapor Pressure of Water[a]

p_v(mm Hg) versus T(°C)

Example: The vapor pressure of liquid water at 4.3°C is 6.230 mm Hg

	T(°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
↓	−14	1.361	1.348	1.336	1.324	1.312	1.300	1.288	1.276	1.264	1.253
	−13	1.490	1.477	1.464	1.450	1.437	1.424	1.411	1.399	1.386	1.373
Ice	−12	1.632	1.617	1.602	1.588	1.574	1.559	1.546	1.532	1.518	1.504
	−11	1.785	1.769	1.753	1.737	1.722	1.707	1.691	1.676	1.661	1.646
	−10	1.950	1.934	1.916	1.899	1.883	1.866	1.849	1.833	1.817	1.800
	−9	2.131	2.122	2.093	2.075	2.057	2.039	2.021	2.003	1.985	1.968
	−8	2.326	2.306	2.285	2.266	2.246	2.226	2.207	2.187	2.168	2.149
	−7	2.537	2.515	2.493	2.472	2.450	2.429	2.408	2.387	2.367	2.346
	−6	2.765	2.742	2.718	2.695	2.672	2.649	2.626	2.603	2.581	2.559
	−5	3.013	2.987	2.962	2.937	2.912	2.887	2.862	2.838	2.813	2.790
	−4	3.280	3.252	3.225	3.198	3.171	3.144	3.117	3.091	3.065	3.039
	−3	3.568	3.539	3.509	3.480	3.451	3.422	3.393	3.364	3.336	3.308
	−2	3.880	3.848	3.816	3.785	3.753	3.722	3.691	3.660	3.630	3.599
	−1	4.217	4.182	4.147	4.113	4.079	4.045	4.012	3.979	3.946	3.913
	−0	4.579	4.542	4.504	4.467	4.431	4.395	4.359	4.323	4.287	4.252
↓	0	4.579	4.613	4.647	4.681	4.715	4.750	4.785	4.820	4.855	4.890
	1	4.926	4.962	4.998	5.034	5.070	5.107	5.144	5.181	5.219	5.256
Liquid	2	5.294	5.332	5.370	5.408	5.447	5.486	5.525	5.565	5.605	5.645
water	3	5.685	5.725	5.766	5.807	5.848	5.889	5.931	5.973	6.015	6.058
	4	6.101	6.144	6.187	6.230	6.274	6.318	6.363	6.408	6.453	6.498
	5	6.543	6.589	6.635	6.681	6.728	6.775	6.822	6.869	6.917	6.965
	6	7.013	7.062	7.111	7.160	7.209	7.259	7.309	7.360	7.411	7.462
	7	7.513	7.565	7.617	7.669	7.722	7.775	7.828	7.882	7.936	7.990
	8	8.045	8.100	8.155	8.211	8.267	8.323	8.380	8.437	8.494	8.551
	9	8.609	8.668	8.727	8.786	8.845	8.905	8.965	9.025	9.086	9.147
	10	9.209	9.271	9.333	9.395	9.458	9.521	9.585	9.649	9.714	9.779
	11	9.844	9.910	9.976	10.042	10.109	10.176	10.244	10.312	10.380	10.449
	12	10.518	10.588	10.658	10.728	10.799	10.870	10.941	11.013	11.085	11.158
	13	11.231	11.305	11.379	11.453	11.528	11.604	11.680	11.756	11.833	11.910
	14	11.987	12.065	12.144	12.223	12.302	12.382	12.462	12.543	12.624	12.706
	15	12.788	12.870	12.953	13.037	13.121	13.205	13.290	13.375	13.461	13.547
	16	13.634	13.721	13.809	13.898	13.987	14.076	14.166	14.256	14.347	14.438
	17	14.530	14.622	14.715	14.809	14.903	14.997	15.092	15.188	15.284	15.380
	18	15.477	15.575	15.673	15.772	15.871	15.971	16.771	16.171	16.272	16.374
	19	16.477	16.581	16.685	16.789	16.894	16.999	17.105	17.212	17.319	17.427
	20	17.535	17.644	17.753	17.863	17.974	18.085	18.197	18.309	18.422	18.536
	21	18.650	18.765	18.880	18.996	19.113	19.231	19.349	19.468	19.587	19.707
	22	19.827	19.948	20.070	20.193	20.316	20.440	20.565	20.690	20.815	20.941
	23	21.068	21.196	21.324	21.453	21.583	21.714	21.845	21.977	22.110	22.243
	24	22.377	22.512	22.648	22.785	22.922	23.060	23.198	23.337	23.476	23.616

[a]From R. H. Perry and C. H. Chilton, Eds., *Chemical Engineers' Handbook*, 5th Edition, McGraw-Hill, New York, 1973, Tables 3-3 and 3-5. Reprinted by permission of McGraw-Hill Book Co.

(*continued*)

Table B.3 (Continued)

T(°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
25	23.756	23.897	24.039	24.182	24.326	24.471	24.617	24.764	24.912	25.060
26	25.209	25.359	25.509	25.660	25.812	25.964	26.117	26.271	26.426	26.582
27	26.739	26.897	27.055	27.214	27.374	27.535	27.696	27.858	28.021	28.185
28	28.349	28.514	28.680	28.847	29.015	29.184	29.354	29.525	29.697	29.870
29	30.043	30.217	30.392	30.568	30.745	30.923	31.102	31.281	31.461	31.642
30	31.824	32.007	32.191	32.376	32.561	32.747	32.934	33.122	33.312	33.503
31	33.695	33.888	34.082	34.276	34.471	34.667	34.864	35.062	35.261	35.462
32	35.663	35.865	36.068	36.272	36.477	36.683	36.891	37.099	37.308	37.518
33	37.729	37.942	38.155	38.369	33.584	38.801	38.018	39.237	39.457	39.677
34	39.898	40.121	40.344	40.569	40.796	41.023	41.251	41.480	41.710	41.942
35	42.175	42.409	42.644	42.880	43.117	43.355	43.595	43.836	44.078	44.320
36	44.563	44.808	45.054	45.301	45.549	45.799	46.050	46.302	46.556	46.811
37	47.067	47.324	47.582	47.841	48.102	48.364	48.627	48.891	49.157	49.424
38	49.692	49.961	50.231	50.502	50.774	51.048	51.323	51.600	51.879	52.160
39	52.442	52.725	53.009	53.294	53.580	53.867	54.156	54.446	54.737	55.030
40	55.324	55.61	55.91	56.21	56.51	56.81	57.11	57.41	57.72	58.03
41	58.34	58.65	58.96	59.27	59.58	59.90	60.22	60.54	60.86	61.18
42	61.50	61.82	62.14	62.47	62.80	63.13	63.46	63.79	64.12	64.46
43	64.80	65.14	65.48	65.82	66.16	66.51	66.86	67.21	67.56	67.91
44	68.26	68.61	68.97	69.33	69.69	70.05	70.41	70.77	71.14	71.51
45	71.88	72.25	72.62	72.99	73.36	73.74	74.12	74.50	74.88	75.26
46	75.65	76.04	76.43	76.82	77.21	77.60	78.00	78.40	78.80	79.20
47	79.60	80.00	80.41	80.82	81.23	81.64	82.05	82.46	82.87	83.29
48	83.71	84.13	84.56	84.99	85.42	85.85	86.28	86.71	87.14	87.58
49	88.02	88.46	88.90	89.34	89.79	90.24	90.69	91.14	91.59	92.05

T(°C)	0	1	2	3	4	5	6	7	8	9
50	92.51	97.20	102.09	107.20	112.51	118.04	123.80	129.82	136.08	142.60
60	149.38	156.43	163.77	171.38	179.31	187.54	196.09	204.96	214.17	223.73
70	233.7	243.9	254.6	265.7	277.2	289.1	301.4	314.1	327.3	341.0
80	355.1	369.7	384.9	400.6	416.8	433.6	450.9	468.7	487.1	506.1

T(°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
90	525.76	527.76	529.77	531.78	533.80	535.82	537.86	539.90	541.95	544.00
91	546.05	548.11	550.18	552.26	554.35	556.44	558.53	560.64	562.75	564.87
92	566.99	569.12	571.26	573.40	575.55	577.71	579.87	582.04	584.22	586.41
93	588.60	590.80	593.00	595.21	597.43	599.66	601.89	604.13	606.38	608.64
94	610.90	613.17	615.44	617.72	620.01	622.31	624.61	626.92	629.24	631.57
95	633.90	636.24	938.59	640.94	643.30	645.67	648.05	650.43	652.82	655.22
96	657.62	660.03	662.45	664.88	667.31	669.75	672.20	674.66	677.12	679.69
97	682.07	684.55	687.04	689.54	692.05	694.57	697.10	699.63	702.17	704.71
98	707.27	709.83	712.40	714.98	717.56	720.15	722.75	725.36	727.98	730.61
99	733.24	735.88	738.53	741.18	743.85	746.52	749.20	751.89	754.58	757.29
100	760.00	762.72	765.45	768.19	770.93	773.68	776.44	779.22	782.00	784.78
101	787.57	790.37	793.18	796.00	798.82	801.66	804.50	807.35	810.21	813.08