UNIVERSITI
TEKNOLOGI
PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE	:	**CEB2023/CFB2023 - CHEMICAL ENGINEERING THERMODYNAMICS II**
DATE	:	**30 JULY 2024 (TUESDAY)**
TIME	:	**9.00 AM - 12.00 NOON (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **EIGHTEEN (18)** pages in this Question Booklet including the cover page and appendices.

ii. **DOUBLE-SIDED** Question Booklet.

iii. **Graph paper will be provided.**

1. One mole of an ideal gas at 5 bar and 900 K is cooled at constant volume to 400 K. It is then heated at constant pressure until its temperature reaches 650 K. Assume the heat capacities for the ideal gas are $C_V = (5/2)R$ and $C_P = (7/2)R$.

   a. Draw the pressure-volume (P-V) diagram for the process.

   [4 marks]

   b. Determine the heat transferred, Q, work required, W, change in internal energy, ΔU and change in enthalpy, ΔH for each process in J.

   [14 marks]

   c. The two-step processes may be replaced by a single adiabatic expansion of gas from 900 K and 5 bar to a final temperature and pressure. Determine the final temperature and pressure for the adiabatic expansion process, if the work of the adiabatic expansion process is equivalent to the work of the two processes.

   [6 marks]

2. a. An insulated tank contains ethanol vapor at 480°C and 49.2 bar.

i. Estimate the molar volume of ethanol vapor using an appropriate equation or correlation.

[8 marks]

ii. Rationalize why the equation or correlation in **part a(i)** is selected.

[3 marks]

iii. Estimate the residual entropy, S^R (J/mol.K).

[5 marks]

b. Steam undergoes an isothermal change of state from 8000 kPa and 400°C to a final state of 350 kPa. Calculate the ratio of the fugacity in the final state to that in the initial state.

[10 marks]

3. a. A binary system of methyl ethyl ketone (1) and toluene (2) forms a phase equilibrium system at 50°C. **TABLE Q3** shows the vapor/liquid equilibrium (VLE) data for the binary system.

TABLE Q3: VLE data for methyl ethyl ketone (1) and toluene (2) at 50°C

P (kPa)	x_1	y_1
12.30	0.0000	0.0000
18.61	0.1981	0.4565
24.01	0.4232	0.6815
27.96	0.6096	0.8050
31.75	0.7934	0.9048
36.09	1.0000	1.0000

The Antoine equations are given below:

$$lnP_1^{sat} = 14.1334 - \frac{2838.24}{t + 218.690}$$

$$lnP_2^{sat} = 13.9320 - \frac{3056.96}{t + 217.625}$$

where, P^{sat} and t are in kPa and °C, respectively. Assume that the modified Raoult's law is valid.

i. Determine the activity coefficient, γ_i, for both components with respect to each composition as stated in **TABLE Q3**.

[7 marks]

ii. Generate a plot of G^E/RT against x_1 where G^E is the excess Gibbs energy and x_1 is the liquid composition of methyl ethyl ketone. Estimate the excess Gibbs energy (J/mol) when x_1 = 0.5.

[9 marks]

iii. Based on **part a(ii)**, explain whether plots of other binary liquid mixtures will exhibit the same shape.

[3 marks]

b. A tank contains binary gas mixture of methyl ethyl ketone (1) and toluene (2) at 70°C and 70 kPa. The experimental virial-coefficient data are $B_{11} = -35.2$ cm^3/mol, $B_{22} = -105.0$ cm^3/mol and $B_{12} = -59.8$ cm^3/mol, respectively. Determine the fugacity coefficients of each component if the mixture contains 65 mole% of methyl ethyl ketone.

[5 marks]

4. Ethylene is produced by the dehydrogenation of ethane as shown below:

$$C_2H_6\ (g) \rightarrow H_2\ (g) + C_2H_4\ (g)$$

For each mole of ethane, 0.5 mol of steam is supplied as an inert diluent for the process. The data for the standard heat of formation, ΔH_f°, and standard Gibbs energy of formation, ΔG_f°, of ethane and ethylene are given in **TABLE Q4.**

TABLE Q4: Standard heat and standard Gibbs of formation at 298.15 K

	ΔH_f° (J/mol)	ΔG_f° (J/mol)
C_2H_6 (g)	−83820	−31855
C_2H_4 (g)	52510	68460

a. Develop expression for the final compositions of the reaction mixture as a function of reaction coordinate, ε.

[4 marks]

b. Determine the equilibrium constant, K, at 1000 K. Assume heat of reaction is constant.

[6 marks]

c. Estimate the equilibrium composition in the mixture at 1000 K and 3 bar. Assume the reaction mixture behaves as an ideal gas.

[6 marks]

d. Based on **part (c)**, propose **TWO (2)** methods to increase the production of ethylene. Justify your answer with suitable calculations.

[10 marks]

-END OF PAPER-

APPENDIX A

List of Formula

1. **Adiabatic Equations at Constant Heat Capacities for Ideal Gases**

$TV^{\gamma-1} = \text{constant}$

$TP^{(1-\gamma)/\gamma} = \text{constant}$

$PV^{\gamma} = \text{constant}$

$$\gamma = \frac{C_p}{C_V}$$

2. **Generalized correlations for the compressibility factor**

$$Z = Z^0 + \omega Z^1$$

3. **Generalized Property Second Virial Correlations for Gases**

$$Z = 1 + \hat{B}\frac{P_r}{T_r}$$

$$\hat{B} = B^0 + \omega B^1$$

$$B^0 = 0.083 - \frac{0.422}{T_r^{1.6}}$$

$$B^1 = 0.139 - \frac{0.172}{T_r^{4.2}}$$

4. **Residual Properties: Generalized Property Correlations for Gases**

$$\frac{S^R}{R} = \frac{(S^R)^0}{R} + \omega\frac{(S^R)^1}{R}$$

5. **Generic Cubic Equations of State: Vapor and Vapor-Like Roots**

$$Z = 1 + \beta - q\beta\frac{Z-\beta}{(Z+\varepsilon\beta)(Z+\sigma\beta)}$$

$$\beta = \Omega\frac{P_r}{T_r}$$

$$q = \frac{\Psi\alpha(T_r)}{\Omega T_r}$$

Case I ($\epsilon \neq \sigma$): $I = \frac{1}{\sigma-\epsilon}\ln\left(\frac{1+\sigma\rho b}{1+\epsilon\rho b}\right)$

Case II ($\epsilon = \sigma$): $I = \frac{\rho b}{1+\epsilon\rho b} = \frac{\beta}{Z+\epsilon\beta}$

APPENDIX A (Cont'd)

List of Formula

6. Residual Properties: Cubic Equations of State

$$\frac{S^R}{R} = \ln(Z-\beta) + \frac{d\ln\alpha(T_r)}{d\ln T_r} qI$$

7. Parameter Assignments for Equations of State

EOS	$\alpha(T_r)$	σ	ε	Ω	Ψ	Z_C
vdW (1873)	1	0	0	1/8	27/64	3/8
RK (1949)	$T_r^{-1/2}$	1	0	0.086 64	0.427 48	1/3
SRK (1972)	$\alpha_{SRK}(T_r;\omega)^{\dagger}$	1	0	0.086 64	0.427 48	1/3
PR (1976)	$\alpha_{PR}(T_r;\omega)^{\ddagger}$	$1+\sqrt{2}$	$1-\sqrt{2}$	0.077 80	0.457 24	0.307 40

$^{\dagger}\ \alpha_{SRK}(T_r;\omega) = [1+(0.480+1.574\omega-0.176\omega^2)(1-T_r^{1/2})]^2$

$^{\ddagger}\ \alpha_{PR}(T_r;\omega) = [1+(0.374\,64+1.542\,26\omega-0.269\,92\omega^2)(1-T_r^{1/2})]^2$

8. Gas mixtures

$$\omega \equiv \sum_i y_i \omega_i$$

$$T_{pc} \equiv \sum_i y_i T_{c_i}$$

$$P_{pc} \equiv \sum_i y_i P_{c_i}$$

9. Relation between Gibbs Free Energy and fugacity of pure species

$$G_i \equiv \Gamma_i(T) + RT\ ln\ f_i$$

10. Excess Gibbs Free Energy

$$\frac{G^E}{RT} = \sum_i x_i\ ln\ \gamma_i$$

$$ln\ \gamma_i = \left[\frac{\partial(nG^E/RT)}{\partial n_i}\right]_{P,\,T,\,n_j}$$

APPENDIX A (Cont'd)

List of Formula

11. Fugacity Coefficients

$$\widehat{ln\,\varphi_1} = \frac{P}{RT}(B_{11} + y_2^2\delta_{12})$$

$$\widehat{ln\,\varphi_2} = \frac{P}{RT}(B_{22} + y_1^2\delta_{12})$$

$$\delta_{12} = 2B_{12} - B_{11} - B_{22}$$

12. Standard Gibbs Energy Change on Reaction

$$K = exp\left(-\frac{\sum v_i\,\Delta G_f{}^0}{RT}\right)$$

13. Temperature Dependence of Reaction Equilibrium Constant

$$-\frac{\Delta H_{rxn}{}^0}{R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right] = ln\left[\frac{K_2}{K_1}\right]$$

14. Relation of Equilibrium constant to composition

$$\prod_i (y_i)^{v_i} = \left(\frac{P}{P_0}\right)^{-v} K$$

15. Values of the Universal Gas Constant

$$\begin{aligned} R &= 8.314\ \text{J mol}^{-1}\ \text{K}^{-1} = 8.314\ \text{m}^3\ \text{Pa mol}^{-1}\ \text{K}^{-1} \\ &= 83.14\ \text{cm}^3\ \text{bar mol}^{-1}\ \text{K}^{-1} = 8314\ \text{cm}^3\ \text{kPa mol}^{-1}\ \text{K}^{-1} \\ &= 82.06\ \text{cm}^3\ \text{atm mol}^{-1}\ \text{K}^{-1} = 62356\ \text{cm}^3\ \text{Torr mol}^{-1}\ \text{K}^{-1} \\ &= 1.987\ \text{(cal) mol}^{-1}\ \text{K}^{-1} = 1.986\ \text{(Btu)(lb mol)}^{-1}(^\circ\text{R})^{-1} \\ &= 1545\ \text{(ft)(lb}_\text{f}\text{)(lb mol)}^{-1}(^\circ\text{R})^{-1} \end{aligned}$$

16. Interpolation

$$M = \left(\frac{X_2 - X}{X_2 - X_1}\right)M_1 + \left(\frac{X - X_1}{X_2 - X_1}\right)M_2$$

$$M = \left[\left(\frac{X_2 - X}{X_2 - X_1}\right)M_{1,1} + \left(\frac{X - X_1}{X_2 - X_1}\right)M_{1,2}\right]\frac{Y_2 - Y}{Y_2 - Y_1} + \left[\left(\frac{X_2 - X}{X_2 - X_1}\right)M_{2,1} + \left(\frac{X - X_1}{X_2 - X_1}\right)M_{2,2}\right]\frac{Y - Y_1}{Y_2 - Y_1}$$

APPENDIX B

Table of Units

Quantity	Conversion	
Length	1 m	= 100 cm = 3.280 84 (ft) = 39.3701 (in)
Mass	1 kg	= 10^3 g = 2.204 62 (lb_m)
Force	1 N	= 1 kg m s^{-2} = 10^5 (dyne) = 0.224 809 (lb_f)
Pressure	1 bar	= 10^5 kg m^{-1} s^{-2} = 10^5 N m^{-2} = 10^5 Pa = 10^2 kPa = 10^6 dyne cm^{-2} = 0.986 923 atm = 14.5038 psia = 750.061 Torr
Volume	1 m^3	= 10^6 cm^3 = 10^3 liters = 35.3147 $(ft)^3$ = 264.172 (gal)
Density	1 g cm^{-3}	= 10^3 kg m^{-3} = 62.4278 (lb_m) $(ft)^{-3}$
Energy	1 J	= 1 kg m^2 s^{-2} = 1 N m = 1 m^3 Pa = 10^{-5} m^3 bar = 10 cm^3 bar = 9.869 23 cm^3 atm = 10^7 (dyne) cm = 10^7 (erg) = 0.239 006 (cal) = 5.121 97 × 10^{-3} $(ft)^3$ (psia) = 0.737 562 (ft) (lb_f) = 9.478 31 × 10^{-4} (Btu) = 2.777 78 × 10^{-7} kWh
Power	1 kW	= 10^3 W = 10^3 kg m^2 s^{-3} = 10^3 J s^{-1} = 239.006 (cal) s^{-1} = 737.562 (ft) (lb_f) s^{-1} = 0.947 831 (Btu) s^{-1} = 1.341 02 (hp)

APPENDIX C

Characteristic Properties of Pure Species

	Molar mass	ω	T_C/K	P_C/bar	Z_C	V_C $cm^3\ mol^{-1}$	T_n/K
Methane	16.043	0.012	190.6	45.99	0.286	98.6	111.4
Ethane	30.070	0.100	305.3	48.72	0.279	145.5	184.6
Propane	44.097	0.152	369.8	42.48	0.276	200.0	231.1
n-Butane	58.123	0.200	425.1	37.96	0.274	255.	272.7
n-Pentane	72.150	0.252	469.7	33.70	0.270	313.	309.2
n-Hexane	86.177	0.301	507.6	30.25	0.266	371.	341.9
n-Heptane	100.204	0.350	540.2	27.40	0.261	428.	371.6
n-Octane	114.231	0.400	568.7	24.90	0.256	486.	398.8
n-Nonane	128.258	0.444	594.6	22.90	0.252	544.	424.0
n-Decane	142.285	0.492	617.7	21.10	0.247	600.	447.3
Isobutane	58.123	0.181	408.1	36.48	0.282	262.7	261.4
Isooctane	114.231	0.302	544.0	25.68	0.266	468.	372.4
Cyclopentane	70.134	0.196	511.8	45.02	0.273	258.	322.4
Cyclohexane	84.161	0.210	553.6	40.73	0.273	308.	353.9
Methylcyclopentane	84.161	0.230	532.8	37.85	0.272	319.	345.0
Methylcyclohexane	98.188	0.235	572.2	34.71	0.269	368.	374.1
Ethylene	28.054	0.087	282.3	50.40	0.281	131.	169.4
Propylene	42.081	0.140	365.6	46.65	0.289	188.4	225.5
1-Butene	56.108	0.191	420.0	40.43	0.277	239.3	266.9
cis-2-Butene	56.108	0.205	435.6	42.23	0.273	233.8	276.9
trans-2-Butene	56.108	0.218	428.6	41.00	0.275	237.7	274.0
1-Hexene	84.161	0.280	504.0	31.40	0.265	354.	336.3
Isobutylene	56.108	0.194	417.9	40.00	0.275	238.9	266.3
1,3-Butadiene	54.092	0.190	425.2	42.77	0.267	220.4	268.7
Cyclohexene	82.145	0.212	560.4	43.50	0.272	291.	356.1
Acetylene	26.038	0.187	308.3	61.39	0.271	113.	189.4
Benzene	78.114	0.210	562.2	48.98	0.271	259.	353.2
Toluene	92.141	0.262	591.8	41.06	0.264	316.	383.8
Ethylbenzene	106.167	0.303	617.2	36.06	0.263	374.	409.4
Cumene	120.194	0.326	631.1	32.09	0.261	427.	425.6
o-Xylene	106.167	0.310	630.3	37.34	0.263	369.	417.6
m-Xylene	106.167	0.326	617.1	35.36	0.259	376.	412.3
p-Xylene	106.167	0.322	616.2	35.11	0.260	379.	411.5
Styrene	104.152	0.297	636.0	38.40	0.256	352.	418.3
Naphthalene	128.174	0.302	748.4	40.51	0.269	413.	491.2
Biphenyl	154.211	0.365	789.3	38.50	0.295	502.	528.2
Formaldehyde	30.026	0.282	408.0	65.90	0.223	115.	254.1
Acetaldehyde	44.053	0.291	466.0	55.50	0.221	154.	294.0
Methyl acetate	74.079	0.331	506.6	47.50	0.257	228.	330.1
Ethyl acetate	88.106	0.366	523.3	38.80	0.255	286.	350.2
Acetone	58.080	0.307	508.2	47.01	0.233	209.	329.4
Methyl ethyl ketone	72.107	0.323	535.5	41.50	0.249	267.	352.8
Diethyl ether	74.123	0.281	466.7	36.40	0.263	280.	307.6
Methyl *t*-butyl ether	88.150	0.266	497.1	34.30	0.273	329.	328.4

APPENDIX C

Characteristic Properties of Pure Species (Cont'd)

	Molar mass	ω	T_C/K	P_C/bar	Z_C	V_C $cm^3\ mol^{-1}$	T_n/K
Methanol	32.042	0.564	512.6	80.97	0.224	118.	337.9
Ethanol	46.069	0.645	513.9	61.48	0.240	167.	351.4
1-Propanol	60.096	0.622	536.8	51.75	0.254	219.	370.4
1-Butanol	74.123	0.594	563.1	44.23	0.260	275.	390.8
1-Hexanol	102.177	0.579	611.4	35.10	0.263	381.	430.6
2-Propanol	60.096	0.668	508.3	47.62	0.248	220.	355.4
Phenol	94.113	0.444	694.3	61.30	0.243	229.	455.0
Ethylene glycol	62.068	0.487	719.7	77.00	0.246	191.0	470.5
Acetic acid	60.053	0.467	592.0	57.86	0.211	179.7	391.1
n-Butyric acid	88.106	0.681	615.7	40.64	0.232	291.7	436.4
Benzoic acid	122.123	0.603	751.0	44.70	0.246	344.	522.4
Acetonitrile	41.053	0.338	545.5	48.30	0.184	173.	354.8
Methylamine	31.057	0.281	430.1	74.60	0.321	154.	266.8
Ethylamine	45.084	0.285	456.2	56.20	0.307	207.	289.7
Nitromethane	61.040	0.348	588.2	63.10	0.223	173.	374.4
Carbon tetrachloride	153.822	0.193	556.4	45.60	0.272	276.	349.8
Chloroform	119.377	0.222	536.4	54.72	0.293	239.	334.3
Dichloromethane	84.932	0.199	510.0	60.80	0.265	185.	312.9
Methyl chloride	50.488	0.153	416.3	66.80	0.276	143.	249.1
Ethyl chloride	64.514	0.190	460.4	52.70	0.275	200.	285.4
Chlorobenzene	112.558	0.250	632.4	45.20	0.265	308.	404.9
Tetrafluoroethane	102.030	0.327	374.2	40.60	0.258	198.0	247.1
Argon	39.948	0.000	150.9	48.98	0.291	75.6	87.3
Krypton	83.800	0.000	209.4	55.02	0.288	91.2	119.8
Xenon	131.30	0.000	289.7	58.40	0.286	118.0	165.0
Helium 4	4.003	−0.390	5.2	2.28	0.302	57.3	4.2
Hydrogen	2.016	−0.216	33.19	13.13	0.305	64.1	20.4
Oxygen	31.999	0.022	154.6	50.43	0.288	73.4	90.2
Nitrogen	28.014	0.038	126.2	34.00	0.289	89.2	77.3
Air	28.851	0.035	132.2	37.45	0.289	84.8	
Chlorine	70.905	0.069	417.2	77.10	0.265	124.	239.1
Carbon monoxide	28.010	0.048	132.9	34.99	0.299	93.4	81.7
Carbon dioxide	44.010	0.224	304.2	73.83	0.274	94.0	
Carbon disulfide	76.143	0.111	552.0	79.00	0.275	160.	319.4
Hydrogen sulfide	34.082	0.094	373.5	89.63	0.284	98.5	212.8
Sulfur dioxide	64.065	0.245	430.8	78.84	0.269	122.	263.1
Sulfur trioxide	80.064	0.424	490.9	82.10	0.255	127.	317.9
Nitric oxide (NO)	30.006	0.583	180.2	64.80	0.251	58.0	121.4
Nitrous oxide (N_2O)	44.013	0.141	309.6	72.45	0.274	97.4	184.7
Hydrogen chloride	36.461	0.132	324.7	83.10	0.249	81.	188.2
Hydrogen cyanide	27.026	0.410	456.7	53.90	0.197	139.	298.9
Water	18.015	0.345	647.1	220.55	0.229	55.9	373.2
Ammonia	17.031	0.253	405.7	112.80	0.242	72.5	239.7
Nitric acid	63.013	0.714	520.0	68.90	0.231	145.	356.2
Sulfuric acid	98.080	...	924.0	64.00	0.147	177.	610.0

APPENDIX D
Steam Tables: Superheated Steam

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

P/kPa (t_sat/°C)		sat. liq	sat. vap.	TEMPERATURE: t/°C (TEMPERATURE: T/kelvins) 325 (598.15)	350 (623.15)	400 (673.15)	450 (723.15)	500 (773.15)	550 (823.15)	600 (873.15)	650 (923.15)
	V	1.076	561.75	843.68	879.78	951.73	1023.5	1095.0	1166.5	1237.9	1309.2
325	U	572.847	2545.7	2845.9	2885.5	2965.5	3046.9	3129.8	3214.4	3300.6	3388.6
(136.29)	H	573.197	2728.3	3120.1	3171.4	3274.8	3379.5	3485.7	3593.5	3702.9	3814.1
	S	1.7004	6.9640	7.7530	7.8369	7.9965	8.1465	8.2885	8.4236	8.5527	8.6764
	V	1.079	524.00	783.01	816.57	883.45	950.11	1016.6	1083.0	1149.3	1215.6
350	U	583.892	2548.2	2845.6	2885.1	2965.2	3046.6	3129.6	3214.2	3300.5	3388.4
(138.87)	H	584.270	2731.6	3119.6	3170.9	3274.4	3379.2	3485.4	3593.3	3702.7	3813.9
	S	1.7273	6.9392	7.7181	7.8022	7.9619	8.1120	8.2540	8.3892	8.5183	8.6421
	V	1.081	491.13	730.42	761.79	824.28	886.54	948.66	1010.7	1072.6	1134.5
375	U	594.332	2550.6	2845.2	2884.8	2964.9	3046.4	3129.4	3214.0	3300.3	3388.3
(141.31)	H	594.737	2734.7	3119.1	3170.5	3274.0	3378.8	3485.1	3593.0	3702.5	3813.7
	S	1.7526	6.9160	7.6856	7.7698	7.9296	8.0798	8.2219	8.3571	8.4863	8.6101
	V	1.084	462.22	684.41	713.85	772.50	830.92	889.19	947.35	1005.4	1063.4
400	U	604.237	2552.7	2844.8	2884.5	2964.6	3046.2	3129.2	3213.8	3300.2	3388.2
(143.62)	H	604.670	2737.6	3118.5	3170.0	3273.6	3378.5	3484.9	3592.8	3702.3	3813.5
	S	1.7764	6.8943	7.6552	7.7395	7.8994	8.0497	8.1919	8.3271	8.4563	8.5802
	V	1.086	436.61	643.81	671.56	726.81	781.84	836.72	891.49	946.17	1000.8
425	U	613.667	2554.8	2844.4	2884.1	2964.4	3045.9	3129.0	3213.7	3300.0	3388.0
(145.82)	H	614.128	2740.3	3118.0	3169.5	3273.3	3378.2	3484.6	3592.5	3702.1	3813.4
	S	1.7990	6.8739	7.6265	7.7109	7.8710	8.0214	8.1636	8.2989	8.4282	8.5520
	V	1.088	413.75	607.73	633.97	686.20	738.21	790.07	841.83	893.50	945.10
450	U	622.672	2556.7	2844.0	2883.8	2964.1	3045.7	3128.8	3213.5	3299.8	3387.9
(147.92)	H	623.162	2742.9	3117.5	3169.1	3272.9	3377.9	3484.3	3592.3	3701.9	3813.2
	S	1.8204	6.8547	7.5995	7.6840	7.8442	7.9947	8.1370	8.2723	8.4016	8.5255
	V	1.091	393.22	575.44	600.33	649.87	699.18	748.34	797.40	846.37	895.27
475	U	631.294	2558.5	2843.6	2883.4	2963.8	3045.4	3128.6	3213.3	3299.7	3387.7
(149.92)	H	631.812	2745.3	3116.9	3168.6	3272.5	3377.6	3484.0	3592.1	3701.7	3813.0
	S	1.8408	6.8365	7.5739	7.6585	7.8189	7.9694	8.1118	8.2472	8.3765	8.5004
	V	1.093	374.68	546.38	570.05	617.16	664.05	710.78	757.41	803.95	850.42
500	U	639.569	2560.2	2843.2	2883.1	2963.5	3045.2	3128.4	3213.1	3299.5	3387.6
(151.84)	H	640.116	2747.5	3116.4	3168.1	3272.1	3377.2	3483.8	3591.8	3701.5	3812.8
	S	1.8604	6.8192	7.5496	7.6343	7.7948	7.9454	8.0879	8.2233	8.3526	8.4766

APPENDIX D

Steam Tables: Superheated Steam (Cont'd)

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

P/kPa (t_sat/°C)		sat. liq.	sat. vap.	TEMPERATURE: t/°C (TEMPERATURE: T/kelvins) 280 (553.15)	290 (563.15)	300 (573.15)	325 (598.15)	350 (623.15)	375 (648.15)	400 (673.15)	425 (698.15)
	V	1.338	29.223	.....	30.490	31.911	35.038	37.781	40.287	42.636	44.874
6600	U	1237.6	2585.5	.....	2614.9	2647.7	2719.0	2780.4	2835.8	2887.5	2936.7
(281.84)	H	1246.5	2778.3	.....	2816.1	2858.4	2950.2	3029.7	3101.7	3168.9	3232.9
	S	3.0853	5.8452	.....	5.9129	5.9872	6.1442	6.2744	6.3877	6.4894	6.5828
	V	1.342	28.741	.....	29.850	31.273	34.391	37.116	39.601	41.927	44.141
6700	U	1242.8	2584.6	.....	2610.8	2644.2	2716.4	2778.3	2834.1	2886.1	2935.5
(282.84)	H	1251.8	2777.1	.....	2810.8	2853.7	2946.8	3027.0	3099.5	3167.0	3231.3
	S	3.0946	5.8379	.....	5.8980	5.9736	6.1326	6.2640	6.3781	6.4803	6.5741
	V	1.345	28.272	.....	29.226	30.652	33.762	36.470	38.935	41.239	43.430
6800	U	1247.9	2583.7	.....	2606.6	2640.6	2713.7	2776.2	2832.4	2884.7	2934.3
(283.84)	H	1257.0	2775.9	.....	2805.3	2849.0	2943.3	3024.2	3097.2	3165.1	3229.6
	S	3.1038	5.8306	.....	5.8830	5.9599	6.1211	6.2537	6.3686	6.4713	6.5655
	V	1.351	27.373	.....	28.024	29.457	32.556	35.233	37.660	39.922	42.068
7000	U	1258.0	2581.8	.....	2597.9	2633.2	2708.4	2772.1	2829.0	2881.8	2931.8
(285.79)	H	1267.4	2773.5	.....	2794.1	2839.4	2936.3	3018.7	3092.7	3161.2	3226.3
	S	3.1219	5.8162	.....	5.8530	5.9327	6.0982	6.2333	6.3497	6.4536	6.5485
	V	1.358	26.522	.....	26.878	28.321	31.413	34.063	36.454	38.676	40.781
7200	U	1267.9	2579.9	.....	2589.0	2625.6	2702.9	2767.8	2825.6	2878.9	2929.4
(287.70)	H	1277.6	2770.9	.....	2782.5	2829.5	2929.1	3013.1	3088.1	3157.4	3223.0
	S	3.1397	5.8020	.....	5.8226	5.9054	6.0755	6.2132	6.3312	6.4362	6.5319
	V	1.364	25.715	.....	25.781	27.238	30.328	32.954	35.312	37.497	39.564
7400	U	1277.6	2578.0	.....	2579.7	2617.8	2697.3	2763.5	2822.1	2876.0	2926.9
(289.57)	H	1287.7	2768.3	.....	2770.5	2819.3	2921.8	3007.4	3083.4	3153.5	3219.6
	S	3.1571	5.7880	.....	5.7919	5.8779	6.0530	6.1933	6.3130	6.4190	6.5156
	V	1.371	24.949	.....	.....	26.204	29.297	31.901	34.229	36.380	38.409
7600	U	1287.2	2575.9	.....	.....	2609.7	2691.7	2759.2	2818.6	2873.1	2924.3
(291.41)	H	1297.6	2765.5	.....	.....	2808.8	2914.3	3001.6	3078.7	3149.6	3216.3
	S	3.1742	5.7742	.....	.....	5.8503	6.0306	6.1737	6.2950	6.4022	6.4996
	V	1.378	24.220	.....	.....	25.214	28.315	30.900	33.200	35.319	37.314
7800	U	1296.7	2573.8	.....	.....	2601.3	2685.9	2754.8	2815.1	2870.1	2921.8
(293.21)	H	1307.4	2762.8	.....	.....	2798.0	2906.7	2995.8	3074.0	3145.6	3212.9
	S	3.1911	5.7605	.....	.....	5.8224	6.0082	6.1542	6.2773	6.3857	6.4839
	V	1.384	23.525	.....	.....	24.264	27.378	29.948	32.222	34.310	36.273
8000	U	1306.0	2571.7	.....	.....	2592.7	2679.9	2750.3	2811.5	2867.1	2919.3
(294.97)	H	1317.1	2759.9	.....	.....	2786.8	2899.0	2989.9	3069.2	3141.6	3209.5
	S	3.2076	5.7471	.....	.....	5.7942	5.9860	6.1349	6.2599	6.3694	6.4684

APPENDIX E

Values of Z^0

$P_r =$	0.0100	0.0500	0.1000	0.2000	0.4000	0.6000	0.8000	1.0000
T_r								
0.30	*0.0029*	*0.0145*	*0.0290*	*0.0579*	*0.1158*	*0.1737*	*0.2315*	0.2892
0.35	*0.0026*	*0.0130*	*0.0261*	*0.0522*	*0.1043*	*0.1564*	*0.2084*	0.2604
0.40	*0.0024*	*0.0119*	*0.0239*	*0.0477*	*0.0953*	*0.1429*	*0.1904*	0.2379
0.45	*0.0022*	*0.0110*	*0.0221*	*0.0442*	*0.0882*	*0.1322*	*0.1762*	0.2200
0.50	*0.0021*	*0.0103*	*0.0207*	*0.0413*	*0.0825*	*0.1236*	*0.1647*	0.2056
0.55	0.9804	*0.0098*	*0.0195*	*0.0390*	*0.0778*	*0.1166*	*0.1553*	0.1939
0.60	0.9849	*0.0093*	*0.0186*	*0.0371*	*0.0741*	*0.1109*	*0.1476*	0.1842
0.65	0.9881	0.9377	*0.0178*	*0.0356*	*0.0710*	*0.1063*	*0.1415*	0.1765
0.70	0.9904	0.9504	0.8958	*0.0344*	*0.0687*	*0.1027*	*0.1366*	0.1703
0.75	0.9922	0.9598	0.9165	*0.0336*	*0.0670*	*0.1001*	*0.1330*	0.1656
0.80	0.9935	0.9669	0.9319	0.8539	*0.0661*	*0.0985*	*0.1307*	0.1626
0.85	0.9946	0.9725	0.9436	0.8810	*0.0661*	*0.0983*	*0.1301*	0.1614
0.90	0.9954	0.9768	0.9528	0.9015	0.7800	*0.1006*	*0.1321*	0.1630
0.93	0.9959	0.9790	0.9573	0.9115	0.8059	0.6635	*0.1359*	0.1664
0.95	0.9961	0.9803	0.9600	0.9174	0.8206	0.6967	*0.1410*	0.1705
0.97	0.9963	0.9815	0.9625	0.9227	0.8338	0.7240	0.5580	0.1779
0.98	0.9965	0.9821	0.9637	0.9253	0.8398	0.7360	0.5887	0.1844
0.99	0.9966	0.9826	0.9648	0.9277	0.8455	0.7471	0.6138	0.1959
1.00	0.9967	0.9832	0.9659	0.9300	0.8509	0.7574	0.6355	0.2901
1.01	0.9968	0.9837	0.9669	0.9322	0.8561	0.7671	0.6542	0.4648
1.02	0.9969	0.9842	0.9679	0.9343	0.8610	0.7761	0.6710	0.5146
1.05	0.9971	0.9855	0.9707	0.9401	0.8743	0.8002	0.7130	0.6026
1.10	0.9975	0.9874	0.9747	0.9485	0.8930	0.8323	0.7649	0.6880
1.15	0.9978	0.9891	0.9780	0.9554	0.9081	0.8576	0.8032	0.7443
1.20	0.9981	0.9904	0.9808	0.9611	0.9205	0.8779	0.8330	0.7858
1.30	0.9985	0.9926	0.9852	0.9702	0.9396	0.9083	0.8764	0.8438
1.40	0.9988	0.9942	0.9884	0.9768	0.9534	0.9298	0.9062	0.8827
1.50	0.9991	0.9954	0.9909	0.9818	0.9636	0.9456	0.9278	0.9103
1.60	0.9993	0.9964	0.9928	0.9856	0.9714	0.9575	0.9439	0.9308
1.70	0.9994	0.9971	0.9943	0.9886	0.9775	0.9667	0.9563	0.9463
1.80	0.9995	0.9977	0.9955	0.9910	0.9823	0.9739	0.9659	0.9583
1.90	0.9996	0.9982	0.9964	0.9929	0.9861	0.9796	0.9735	0.9678
2.00	0.9997	0.9986	0.9972	0.9944	0.9892	0.9842	0.9796	0.9754
2.20	0.9998	0.9992	0.9983	0.9967	0.9937	0.9910	0.9886	0.9865
2.40	0.9999	0.9996	0.9991	0.9983	0.9969	0.9957	0.9948	0.9941
2.60	1.0000	0.9998	0.9997	0.9994	0.9991	0.9990	0.9990	0.9993
2.80	1.0000	1.0000	1.0001	1.0002	1.0007	1.0013	1.0021	1.0031
3.00	1.0000	1.0002	1.0004	1.0008	1.0018	1.0030	1.0043	1.0057
3.50	1.0001	1.0004	1.0008	1.0017	1.0035	1.0055	1.0075	1.0097
4.00	1.0001	1.0005	1.0010	1.0021	1.0043	1.0066	1.0090	1.0115

APPENDIX F

Values of Z^1

$P_r =$	0.0100	0.0500	0.1000	0.2000	0.4000	0.6000	0.8000	1.0000
T_r								
0.30	*−0.0008*	*−0.0040*	*−0.0081*	*−0.0161*	*−0.0323*	*−0.0484*	*−0.0645*	−0.0806
0.35	*−0.0009*	*−0.0046*	*−0.0093*	*−0.0185*	*−0.0370*	*−0.0554*	*−0.0738*	−0.0921
0.40	*−0.0010*	*−0.0048*	*−0.0095*	*−0.0190*	*−0.0380*	*−0.0570*	*−0.0758*	−0.0946
0.45	*−0.0009*	*−0.0047*	*−0.0094*	*−0.0187*	*−0.0374*	*−0.0560*	*−0.0745*	−0.0929
0.50	*−0.0009*	*−0.0045*	*−0.0090*	*−0.0181*	*−0.0360*	*−0.0539*	*−0.0716*	−0.0893
0.55	−0.0314	*−0.0043*	*−0.0086*	*−0.0172*	*−0.0343*	*−0.0513*	*−0.0682*	−0.0849
0.60	−0.0205	*−0.0041*	*−0.0082*	*−0.0164*	*−0.0326*	*−0.0487*	*−0.0646*	−0.0803
0.65	−0.0137	−0.0772	*−0.0078*	*−0.0156*	*−0.0309*	*−0.0461*	*−0.0611*	−0.0759
0.70	−0.0093	−0.0507	−0.1161	*−0.0148*	*−0.0294*	*−0.0438*	*−0.0579*	−0.0718
0.75	−0.0064	−0.0339	−0.0744	*−0.0143*	*−0.0282*	*−0.0417*	*−0.0550*	−0.0681
0.80	−0.0044	−0.0228	−0.0487	−0.1160	*−0.0272*	*−0.0401*	*−0.0526*	−0.0648
0.85	−0.0029	−0.0152	−0.0319	−0.0715	*−0.0268*	*−0.0391*	*−0.0509*	−0.0622
0.90	−0.0019	−0.0099	−0.0205	−0.0442	−0.1118	*−0.0396*	*−0.0503*	−0.0604
0.93	−0.0015	−0.0075	−0.0154	−0.0326	−0.0763	−0.1662	*−0.0514*	−0.0602
0.95	−0.0012	−0.0062	−0.0126	−0.0262	−0.0589	−0.1110	*−0.0540*	−0.0607
0.97	−0.0010	−0.0050	−0.0101	−0.0208	−0.0450	−0.0770	−0.1647	−0.0623
0.98	−0.0009	−0.0044	−0.0090	−0.0184	−0.0390	−0.0641	−0.1100	−0.0641
0.99	−0.0008	−0.0039	−0.0079	−0.0161	−0.0335	−0.0531	−0.0796	−0.0680
1.00	−0.0007	−0.0034	−0.0069	−0.0140	−0.0285	−0.0435	−0.0588	−0.0879
1.01	−0.0006	−0.0030	−0.0060	−0.0120	−0.0240	−0.0351	−0.0429	−0.0223
1.02	−0.0005	−0.0026	−0.0051	−0.0102	−0.0198	−0.0277	−0.0303	−0.0062
1.05	−0.0003	−0.0015	−0.0029	−0.0054	−0.0092	−0.0097	−0.0032	0.0220
1.10	0.0000	0.0000	0.0001	0.0007	0.0038	0.0106	0.0236	0.0476
1.15	0.0002	0.0011	0.0023	0.0052	0.0127	0.0237	0.0396	0.0625
1.20	0.0004	0.0019	0.0039	0.0084	0.0190	0.0326	0.0499	0.0719
1.30	0.0006	0.0030	0.0061	0.0125	0.0267	0.0429	0.0612	0.0819
1.40	0.0007	0.0036	0.0072	0.0147	0.0306	0.0477	0.0661	0.0857
1.50	0.0008	0.0039	0.0078	0.0158	0.0323	0.0497	0.0677	0.0864
1.60	0.0008	0.0040	0.0080	0.0162	0.0330	0.0501	0.0677	0.0855
1.70	0.0008	0.0040	0.0081	0.0163	0.0329	0.0497	0.0667	0.0838
1.80	0.0008	0.0040	0.0081	0.0162	0.0325	0.0488	0.0652	0.0814
1.90	0.0008	0.0040	0.0079	0.0159	0.0318	0.0477	0.0635	0.0792
2.00	0.0008	0.0039	0.0078	0.0155	0.0310	0.0464	0.0617	0.0767
2.20	0.0007	0.0037	0.0074	0.0147	0.0293	0.0437	0.0579	0.0719
2.40	0.0007	0.0035	0.0070	0.0139	0.0276	0.0411	0.0544	0.0675
2.60	0.0007	0.0033	0.0066	0.0131	0.0260	0.0387	0.0512	0.0634
2.80	0.0006	0.0031	0.0062	0.0124	0.0245	0.0365	0.0483	0.0598
3.00	0.0006	0.0029	0.0059	0.0117	0.0232	0.0345	0.0456	0.0565
3.50	0.0005	0.0026	0.0052	0.0103	0.0204	0.0303	0.0401	0.0497
4.00	0.0005	0.0023	0.0046	0.0091	0.0182	0.0270	0.0357	0.0443

APPENDIX G

Values of $(S^R)^0/R$

$P_r =$	0.0100	0.0500	0.1000	0.2000	0.4000	0.6000	0.8000	1.0000
T_r								
0.30	*−11.614*	*−10.008*	*−9.319*	*−8.635*	*−7.961*	*−7.574*	*−7.304*	−7.099
0.35	*−11.185*	*−9.579*	*−8.890*	*−8.205*	*−7.529*	*−7.140*	*−6.869*	−6.663
0.40	*−10.802*	*−9.196*	*−8.506*	*−7.821*	*−7.144*	*−6.755*	*−6.483*	−6.275
0.45	*−10.453*	*−8.847*	*−8.157*	*−7.472*	*−6.794*	*−6.404*	*−6.132*	−5.924
0.50	*−10.137*	*−8.531*	*−7.841*	*−7.156*	*−6.479*	*−6.089*	*−5.816*	−5.608
0.55	−0.038	*−8.245*	*−7.555*	*−6.870*	*−6.193*	*−5.803*	*−5.531*	−5.324
0.60	−0.029	*−7.983*	*−7.294*	*−6.610*	*−5.933*	*−5.544*	*−5.273*	−5.066
0.65	−0.023	−0.122	*−7.052*	*−6.368*	*−5.694*	*−5.306*	*−5.036*	−4.830
0.70	−0.018	−0.096	−0.206	*−6.140*	*−5.467*	*−5.082*	*−4.814*	−4.610
0.75	−0.015	−0.078	−0.164	*−5.917*	*−5.248*	*−4.866*	*−4.600*	−4.399
0.80	−0.013	−0.064	−0.134	−0.294	*−5.026*	*−4.694*	*−4.388*	−4.191
0.85	−0.011	−0.054	−0.111	−0.239	*−4.785*	*−4.418*	*−4.166*	−3.976
0.90	−0.009	−0.046	−0.094	−0.199	−0.463	*−4.145*	*−3.912*	−3.738
0.93	−0.008	−0.042	−0.085	−0.179	−0.408	−0.750	*−3.723*	−3.569
0.95	−0.008	−0.039	−0.080	−0.168	−0.377	−0.671	*−3.556*	−3.433
0.97	−0.007	−0.037	−0.075	−0.157	−0.350	−0.607	−1.056	−3.259
0.98	−0.007	−0.036	−0.073	−0.153	−0.337	−0.580	−0.971	−3.142
0.99	−0.007	−0.035	−0.071	−0.148	−0.326	−0.555	−0.903	−2.972
1.00	−0.007	−0.034	−0.069	−0.144	−0.315	−0.532	−0.847	−2.178
1.01	−0.007	−0.033	−0.067	−0.139	−0.304	−0.510	−0.799	−1.391
1.02	−0.006	−0.032	−0.065	−0.135	−0.294	−0.491	−0.757	−1.225
1.05	−0.006	−0.030	−0.060	−0.124	−0.267	−0.439	−0.656	−0.965
1.10	−0.005	−0.026	−0.053	−0.108	−0.230	−0.371	−0.537	−0.742
1.15	−0.005	−0.023	−0.047	−0.096	−0.201	−0.319	−0.452	−0.607
1.20	−0.004	−0.021	−0.042	−0.085	−0.177	−0.277	−0.389	−0.512
1.30	−0.003	−0.017	−0.033	−0.068	−0.140	−0.217	−0.298	−0.385
1.40	−0.003	−0.014	−0.027	−0.056	−0.114	−0.174	−0.237	−0.303
1.50	−0.002	−0.011	−0.023	−0.046	−0.094	−0.143	−0.194	−0.246
1.60	−0.002	−0.010	−0.019	−0.039	−0.079	−0.120	−0.162	−0.204
1.70	−0.002	−0.008	−0.017	−0.033	−0.067	−0.102	−0.137	−0.172
1.80	−0.001	−0.007	−0.014	−0.029	−0.058	−0.088	−0.117	−0.147
1.90	−0.001	−0.006	−0.013	−0.025	−0.051	−0.076	−0.102	−0.127
2.00	−0.001	−0.006	−0.011	−0.022	−0.044	−0.067	−0.089	−0.111
2.20	−0.001	−0.004	−0.009	−0.018	−0.035	−0.053	−0.070	−0.087
2.40	−0.001	−0.004	−0.007	−0.014	−0.028	−0.042	−0.056	−0.070
2.60	−0.001	−0.003	−0.006	−0.012	−0.023	−0.035	−0.046	−0.058
2.80	−0.000	−0.002	−0.005	−0.010	−0.020	−0.029	−0.039	−0.048
3.00	−0.000	−0.002	−0.004	−0.008	−0.017	−0.025	−0.033	−0.041
3.50	−0.000	−0.001	−0.003	−0.006	−0.012	−0.017	−0.023	−0.029
4.00	−0.000	−0.001	−0.002	−0.004	−0.009	−0.013	−0.017	−0.021

APPENDIX H

Values of $(S^R)^1/R$

$P_r =$	0.0100	0.0500	0.1000	0.2000	0.4000	0.6000	0.8000	1.0000
T_r								
0.30	*−16.782*	*−16.774*	*−16.764*	*−16.744*	*−16.705*	*−16.665*	*−16.626*	−16.586
0.35	*−15.413*	*−15.408*	*−15.401*	*−15.387*	*−15.359*	*−15.333*	*−15.305*	−15.278
0.40	*−13.990*	*−13.986*	*−13.981*	*−13.972*	*−13.953*	*−13.934*	*−13.915*	−13.896
0.45	*−12.564*	*−12.561*	*−12.558*	*−12.551*	*−12.537*	*−12.523*	*−12.509*	−12.496
0.50	*−11.202*	*−11.200*	*−11.197*	*−11.092*	*−11.082*	*−11.172*	*−11.162*	−11.153
0.55	−0.115	*−9.948*	*−9.946*	*−9.942*	*−9.935*	*−9.928*	*−9.921*	−9.914
0.60	−0.078	*−8.828*	*−8.826*	*−8.823*	*−8.817*	*−8.811*	*−8.806*	−8.799
0.65	−0.055	−0.309	*−7.832*	*−7.829*	*−7.824*	*−7.819*	*−7.815*	−7.510
0.70	−0.040	−0.216	−0.491	*−6.951*	*−6.945*	*−6.941*	*−6.937*	−6.933
0.75	−0.029	−0.156	−0.340	*−6.173*	*−6.167*	*−6.162*	*−6.158*	−6.155
0.80	−0.022	−0.116	−0.246	−0.578	*−5.475*	*−5.468*	*−5.462*	−5.458
0.85	−0.017	−0.088	−0.183	−0.400	*−4.853*	*−4.841*	*−4.832*	−4.826
0.90	−0.013	−0.068	−0.140	−0.301	−0.744	*−4.269*	*−4.249*	−4.238
0.93	−0.011	−0.058	−0.120	−0.254	−0.593	−1.219	*−3.914*	−3.894
0.95	−0.010	−0.053	−0.109	−0.228	−0.517	−0.961	*−3.697*	−3.658
0.97	−0.010	−0.048	−0.099	−0.206	−0.456	−0.797	−1.570	−3.406
0.98	−0.009	−0.046	−0.094	−0.196	−0.429	−0.734	−1.270	−3.264
0.99	−0.009	−0.044	−0.090	−0.186	−0.405	−0.680	−1.098	−3.093
1.00	−0.008	−0.042	−0.086	−0.177	−0.382	−0.632	−0.977	−2.399
1.01	−0.008	−0.040	−0.082	−0.169	−0.361	−0.590	−0.883	−1.306
1.02	−0.008	−0.039	−0.078	−0.161	−0.342	−0.552	−0.807	−1.113
1.05	−0.007	−0.034	−0.069	−0.140	−0.292	−0.460	−0.642	−0.820
1.10	−0.005	−0.028	−0.055	−0.112	−0.229	−0.350	−0.470	−0.577
1.15	−0.005	−0.023	−0.045	−0.091	−0.183	−0.275	−0.361	−0.437
1.20	−0.004	−0.019	−0.037	−0.075	−0.149	−0.220	−0.286	−0.343
1.30	−0.003	−0.013	−0.026	−0.052	−0.102	−0.148	−0.190	−0.226
1.40	−0.002	−0.010	−0.019	−0.037	−0.072	−0.104	−0.133	−0.158
1.50	−0.001	−0.007	−0.014	−0.027	−0.053	−0.076	−0.097	−0.115
1.60	−0.001	−0.005	−0.011	−0.021	−0.040	−0.057	−0.073	−0.086
1.70	−0.001	−0.004	−0.008	−0.016	−0.031	−0.044	−0.056	−0.067
1.80	−0.001	−0.003	−0.006	−0.013	−0.024	−0.035	−0.044	−0.053
1.90	−0.001	−0.003	−0.005	−0.010	−0.019	−0.028	−0.036	−0.043
2.00	−0.000	−0.002	−0.004	−0.008	−0.016	−0.023	−0.029	−0.035
2.20	−0.000	−0.001	−0.003	−0.006	−0.011	−0.016	−0.021	−0.025
2.40	−0.000	−0.001	−0.002	−0.004	−0.008	−0.012	−0.015	−0.019
2.60	−0.000	−0.001	−0.002	−0.003	−0.006	−0.009	−0.012	−0.015
2.80	−0.000	−0.001	−0.001	−0.003	−0.005	−0.008	−0.010	−0.012
3.00	−0.000	−0.001	−0.001	−0.002	−0.004	−0.006	−0.008	−0.010
3.50	−0.000	−0.000	−0.001	−0.001	−0.003	−0.004	−0.006	−0.007
4.00	−0.000	−0.000	−0.001	−0.001	−0.002	−0.003	−0.005	−0.006