The Viscosity and Thermal Conductivity Coefficients for Dense Gaseous and Liquid Methane

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Data for the viscosity and thermal conductivity coefficients of dense gaseous and liquid methane have been evaluated. Selected data were fitted to a function derived in our previous work and tables of values were generated for temperatures from 95 to 500 K and for pressures up to 50 MPa (~ 500 atm). The uncertainties of the tabular values are estimated to be approximately 3% and 5% for the viscosity and thermal conductivity coefficients, respectively. The contribution for the thermal conductivity enhancement in the critical region is included in the tables. Care has been taken to ensure that the calculated values are consistent with reliable equation-of-state data and also with dilute gas transport coefficients determined previously.

Key words: Correlation; critical point anomaly; methane; tables; thermal conductivity coefficient; viscosity coefficient.

1. Introduction

The viscosity coefficient (η) and the thermal conductivity coefficient (λ) of several fluids—argon, krypton, xenon, oxygen, and nitrogen—have been correlated over a wide range of experimental conditions [1][1]. The correlation was recently extended to methane [2]. The object of this paper is to expand on reference [2] by presenting tables and to give some further details of the correlation. We will follow closely the outline of reference [1] in which criteria for evaluating systematically literature data were discussed and in which an equation for the viscosity and thermal conductivity coefficients was proposed. The criteria and equations will be used here with only minimal comments.

2. Correlating Equations

The correlations are based on the behavior of the transport coefficients with respect to temperature (T) and density (ρ) according to the equations

$$\eta(\rho,T) = \eta_0(T) + \eta_1(T)\rho + \Delta\eta'(\rho,T), \quad (1)$$

$$\lambda(\rho,T) = \lambda_0(T) + \lambda_1(T)\rho + \Delta\lambda'(\rho,T) + \Delta_c\lambda(\rho,T), \quad (2)$$

for the viscosity and thermal conductivity coefficients, respectively. In these equations, $\eta_0(T)$ and $\lambda_0(T)$ are the dilute gas values, $\eta_1(T)$ and $\lambda_1(T)$ represent first density corrections for the moderately dense gas, while $\Delta\eta'(\rho,T)$ and $\Delta\lambda'(\rho,T)$ are remainders. The term $\eta_1(T)$ is given by the empirical expression

$$\eta_1(T) = A + B\,[C - \ln(T/F)]^2, \quad (3)$$

and similarly for $\lambda_1(T)$. The coefficients A, B, C, and F can be found from a fit of data but we set $F = \epsilon/k$ where ϵ is the energy parameter of the methane pair potential function and k is Boltzmann's constant. See section 3.

The terms $\Delta\eta'(\rho,T)$ and $\Delta\lambda'(\rho,T)$ are expressed empirically by the relations

$$\Delta\eta'(\rho,T) = E\{\exp[j_1 + j_4/T] \exp[\rho^{0.1}(j_2 + j_3/T^{3/2}) + \theta\rho^{0.5}(j_5 + j_6/T + j_7/T^2)] - 1.0\}, \quad (4)$$

and

$$\Delta\lambda'(\rho,T) = D\{\exp[k_1 + k_4/T] \exp[\rho^{0.1}(k_2 + k_3/T^{3/2}) + \theta\rho^{0.5}(k_5 + k_6/T + k_7/T^2)] - 1.0\}. \quad (5)$$

The parameter θ is included to account specifically for the high density behavior of the transport coefficients and is a function of the density with respect to the critical density, ρ_c:

$$\theta = (\rho - \rho_c)/\rho_c. \quad (6)$$

The coefficients, E, D, $j_1 \ldots j_7$, $k_1 \ldots k_7$, are all to be determined from experimental data

[1] Numbers in brackets indicate literature references.

One sees that equations (1) and (2) are of the same structure [2] except that equation (2) includes the term $\Delta\lambda_c(\rho,T)$. This is included to take into account the known enhancement of the thermal conductivity coefficient in the neighborhood of the critical point [3]. (The viscosity coefficient also shows anomalous behavior close to the critical point [4]. The anomaly is small, however, and is not included in the calculated values.)

We have remarked in reference [1] that the form of equations (4) and (5) was independent of the nature of the fluids considered. The behavior of methane [2] is consistent with this characteristic. This apparent generality is a useful feature of the equations but, since they are empirical, each fluid should be treated on its merits without prior prejudice.

Equation of State

The majority of transport coefficient data in the literature is reported in temperature-pressure coordinates but we emphasized [1] that a correlation of the coefficients should be preferably in terms of density rather than pressure. An accurate equation of state is, therefore, essential to our procedure. The equation of state used here for methane is a modified Benedict-Webb-Rubin (BWR), which was introduced and discussed in reference [5]. The equation is, in turn, based on the methane correlation of Goodwin [6]. The form of the BWR and values for its parameters are given in the appendix of the present paper.

3. The Dilute Gas

The dilute gas coefficients appear separately in equations (1) and (2). We have discussed the calculation of these quantities from statistical mechanics [7, 8, 9] and have shown, in particular, that statistical mechanics can give a consistent representation of the transport properties and the thermodynamic properties for a simple gas.

Dilute gas transport coefficient data for methane have been listed and evaluated in reference [10]. Calculated values were obtained via the standard kinetic theory equations [9] using the m-6-8 pair potential function of Klein and Hanley [10]. This potential has the form

$$\phi(r) = \frac{\epsilon}{m-6}[6 + 2\gamma']\left(\frac{r_m}{r}\right)^m - \frac{\epsilon}{m-6}[m - \gamma'(m-8)]\left(\frac{r_m}{r}\right)^6 - \gamma'\left(\frac{r_m}{r}\right)^8, \quad (7)$$

where r is the intermolecular separation, ϵ the maximum well-depth of the potential, and r_m is defined according to the relation $\phi(r_m) = -\epsilon$. Repulsive forces between molecules are represented by a $1/r^m$ contribution, while attractive forces are represented by $-1/r^6$ and $-1/r^8$ contributions; γ' depicts the strength of the latter. Since we have discussed the application of kinetic theory to methane in reference [10], details of the calculation procedure are omitted here. m-6-8 methane parameters are given in table 1. The dilute gas data were fitted to within their estimated accuracy (approximately ± 2% for the viscosity coefficient and approximately ± 5% for the thermal conductivity coefficient). Recent work [53] has suggested, however, that the m-6-8 potential can lead to small systematic differences between theory and experiment at very low temperatures [$T/(\epsilon/k) < 0.8$] and at very high temperature [$T/(\epsilon/k) > 20$]. Accordingly we revise our estimate of accuracy for the dilute gas transport coefficients of methane for temperatures less than 150 K to 3% and 6% for the viscosity and thermal conductivity coefficient, respectively. Ely and Hanley have further discussed [9] the approximations introduced when a nonspherical molecule, such as methane, is regarded as spherical from the viewpoint of the pair potential. For methane, we have verified that this assumption does not effect the correlation of a single property (e.g., the viscosity) but effects slightly the consistency between calculated values of different properties.

TABLE 1. Potential function parameters (equation (7)) and critical point parameters for methane.

m	= 11
γ'	= 3.0
r_m	= 4.101 × 10^{-10} m (σ = 3.68 × 10^{-10} m)
ϵ/k	= 168.0 K
T_c	= 190.55 K
P_c	= 4.5988 MPa (45.387 atm)
ρ_c	= 0.1628 g/gm^3 (10.15 mol /l)
molecular weight	= 16.043

For computational convenience we fitted the calculated η_o and λ_o to a polynomial in temperature

$$\eta_o = GV(1)T^{-1} + GV(2)T^{-2/3} + GV(3)T^{-1/3} + GV(4) + GV(5)T^{1/3} + GV(6)T^{2/3} + GV(7)T + GV(8)T^{4/3} + GV(9)T^{5/3} \quad (8)$$

and similarly for λ_o, but with coefficients $GT(i)$ $(i=1 \ldots 9)$ replacing $GV(i)$ in equation (8). Values of the coefficients are listed in table 2.

4. Calculation of the Thermal Conductivity Coefficient in the Critical Region

The quantity $\Delta\lambda_c$ appears as a separate term in equation (2) and represents the anomalous behavior of the thermal

[2] Equation (5) here includes a contribution proportional to θ, unlike the corresponding equation (equation (9)) in reference [1]. In our earlier work with oxygen, nitrogen, and the rare gases, however, the data were either not sufficiently precise, or extensive to justify seven k coefficients.

TABLE 2. Parameters for the dilute gas equation (8). The units are: Temperature in K, viscosity in $\mu g/(cm \cdot s)$, and thermal conductivity in $mW/(m \cdot K)$.

$GV(1) = -2.090975 \times 10^5$	$GT(1) = -2.147621 \times 10^5$
$GV(2) = 2.647269 \times 10^5$	$GT(2) = 2.190461 \times 10^5$
$GV(3) = -1.472818 \times 10^5$	$GT(3) = -8.618097 \times 10^4$
$GV(4) = 4.716740 \times 10^4$	$GT(4) = 1.496099 \times 10^4$
$GV(5) = -9.491872 \times 10^3$	$GT(5) = -4.730660 \times 10^2$
$GV(6) = 1.219979 \times 10^3$	$GT(6) = -2.331178 \times 10^2$
$GV(7) = -9.627993 \times 10^1$	$GT(7) = 3.778439 \times 10^1$
$GV(8) = 4.274152$	$GT(8) = -2.320481$
$GV(9) = -8.141531 \times 10^{-2}$	$GT(9) = 5.311764 \times 10^{-2}$

conductivity coefficient in the neighborhood of the critical point [3]. There is no doubt that $\Delta\lambda_c$ can contribute significantly to the value of the thermal conductivity coefficient and has to be included in a correlation [1]. Conductivity data, however, in the critical region for methane are scarce and we prefer to obtain $\Delta\lambda_c$ by calculation.

The calculation follows a procedure suggested by Sengers [3] and expanded by Hanley, Sengers, and Ely [11]. Details are given in reference [11], in section 3.2 of reference [1], and in reference [2]. Our application to methane is given in appendix C of reference [2].

5. Data Selection and Correlation

Since the dilute gas coefficients, η_o and λ_o, have been calculated previously [10], we considered here data for the dense gas and liquid regions *only*. A comprehensive search of the world's literature through 1975 turned up reference [12] – [37] for the viscosity coefficient and references [38] – [49] for the thermal conductivity. Much of the data prior to 1970 are summarized in references [50] – [52]. The data reported in these papers were examined according to the criteria set out in section 2 of reference [1]. The data used for correlation purposes were chosen on the basis of the procedure described in section 2.3 of reference [1], and table 3 gives the final choices with our accuracy assessments.

We have shown that it is essential to have reliable data close to the saturated liquid boundary and for at least one high temperature (about 2 T_c) isotherm if equations (1) to (5) are to give a reliable correlation. Such data are available for methane. (Conversely, if data are available for the saturated liquid boundary and for one high temperature isotherm *only*, equations (1) to (5) are excellent interpolation functions.)

The experimental coverage for the thermal conductivity coefficient of methane is perhaps the most extensive of any fluid due to the measurements of Mani [39], using a transient hot wire technique, and to those of Le Neindre [38], using a concentric cylinder apparatus. In the region of overlap, data from these two authors differ systematically by about two percent, which is within their estimated uncertainties.

TABLE. 3. Selected references for methane.

Authors	Approximate experimental range	Estimated accuracy ± %
Viscosity		
Haynes [12]	Saturated liquid 95–190 K	2%
Giddings et al. [13]	283–410 K Pressures to 54 MPa	2%
Barua et al. [14]	223–423 K Pressures to 17 MPa	2%
Kestin and Leidenfrost [15]	~ 296 K Pressures to 15 MPa	1%
Boon and Thomaes [16]	Saturated liquid 91–114 K	3%
Thermal conductivity		
Le Neindre [38]	298–723 K Pressures to 100 MPa	4%
Mani [39]	139–400 K Pressures to 60 MPa	3.5%
Ikenberry and Rice [40]	98–235 K Pressures to 50 MPa	5%

5.1. Parameters for Equations (3)–(5)

The parameters for equations (3)–(5) were estimated by the least squares procedure outlined in section 3.1 of reference [1], using the selected data from table 3, and are given in table 4. As remarked, however, thermal conductivity data close to the critical point (from references [39] and [40]) were excluded from the fit; rather $\Delta\lambda_c$ was obtained by calculation [2].

5.2. Deviation Curves

Representative deviation curves are shown as figures 1–4. In every example the percent deviation has been defined as

$$\text{percent deviation} = \frac{(\text{expt.} - \text{calc.})}{\text{expt.}} \times 100. \qquad (9)$$

The figures are self-explanatory and show that we have been able to fit the data to within the estimated experimental uncertainties with one possible exception: namely, the calculated viscosity coefficient appears too low close to the critical point, see figure 1. Although it is possible that experimental error and/or incorrect density values contribute to the deviation, it is more likely that the deviation is the result of a small enhancement in the viscosity close to the critical point [4], which is excluded from the correlating equation. This feature was also observed in our previous work [1].

TABLE 4. Parameters for equations (3)–(5). The units are: Density in g/cm³, temperature in K, viscosity in μg/(cm · s), thermal conductivity in mW/(m · K).

Viscosity	
Equation (3)	A = 1.696985927
	B = −0.133372346
	C = 1.4
	F = 168.0
Equation (4)	E = 1.0
	j_1 = $-1.035060586 \times 10^{1}$
	j_2 = $1.7571599671 \times 10^{1}$
	j_3 = $-3.0193918656 \times 10^{3}$
	j_4 = $1.8873011594 \times 10^{2}$
	j_5 = $4.2903609488 \times 10^{-2}$
	j_6 = $1.4529023444 \times 10^{2}$
	j_7 = $6.1276818706 \times 10^{3}$
Thermal conductivity	
Equation (3)	A = −0.25276292
	B = 0.33432859
	C = 1.12
	F = 168.0
Equation (5)	D = 1.0
	k_1 = −7.0403639907
	k_3 = 12.319512908
	k_2 = $-8.8525979933 \times 10^{2}$
	k_4 = 72.835897919
	k_5 = 0.74421462902
	k_6 = −2.9706914540
	k_7 = $2.2209758501 \times 10^{3}$

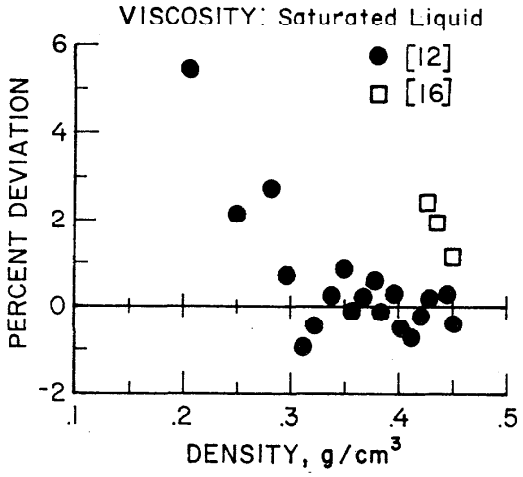

FIGURE 1. Deviations between experiment and calculation for the viscosity of saturated liquid methane.

6. Construction of Tables

We constructed tables of values for the viscosity coefficient (table 5) and the thermal conductivity coefficient (table 6) from equations (1)–(5) with the parameters of table 4 using the equation of state in the appendix. The temperature range is 95 to 500 K. The pressures extend to 50 MPa for temperatures less than 205 K, and to 75 MPa for temperatures between 205 and 500 K. These ranges sometimes correspond to a slight extrapolation of the data. The correlations, however, are based on the temperature-density behavior of the transport coefficients. Density is the limiting variable. We therefore assured that a P-T entry in the table did not correspond to a density exceeding 0.445 g/cm³ (27.8 mole/l), which was the upper experimental limit.

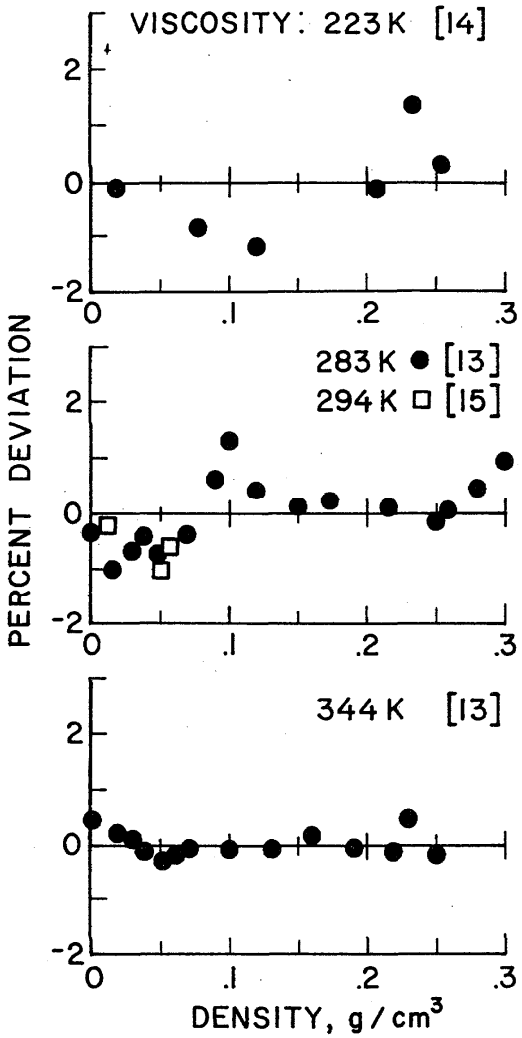

FIGURE 2. Viscosity deviations at several representative temperatures.

For convenience we constructed table 7 which presents values for the saturated liquid.

6.1 Uncertainty of the Tables and Extrapolation

Our assessment of the correlating procedure of reference [1] led to the conclusion that the correlation does not give

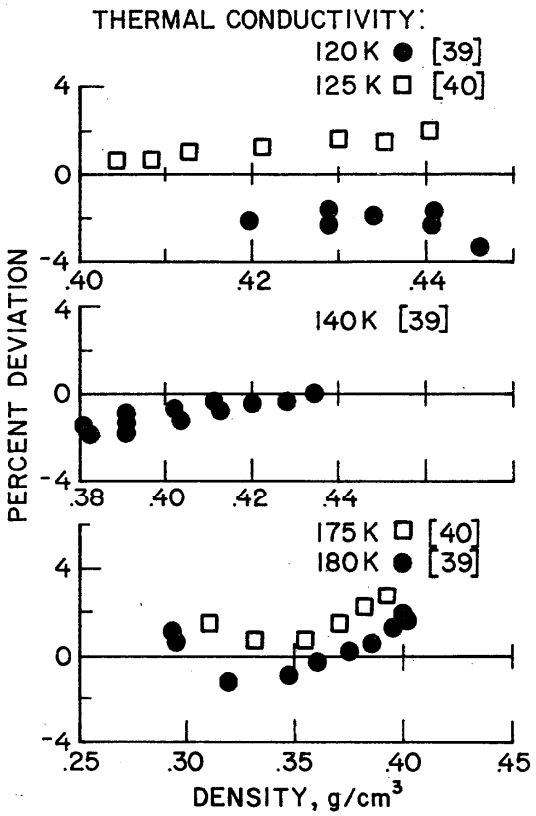

FIGURE 3. Thermal conductivity deviations at low temperature.

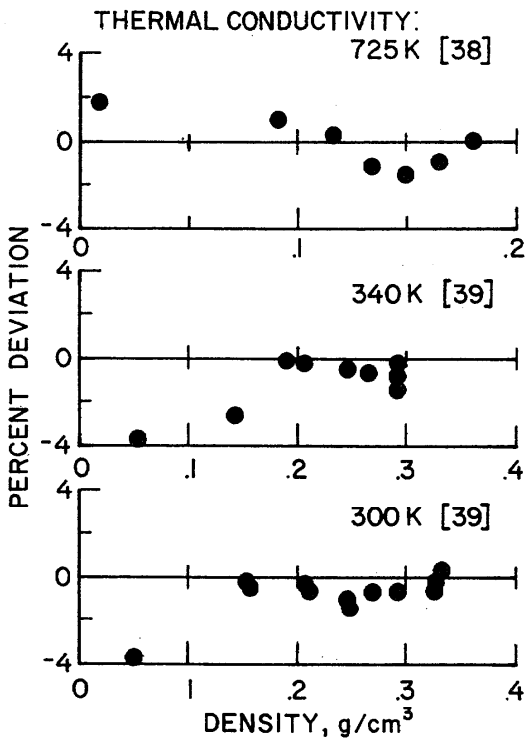

FIGURE 4. Thermal conductivity deviations at representative temperatures above 300 K.

rise to significant systematic deviations between calculated and experimental values of the transport coefficients. This conclusion is reinforced from this work with methane. Hence, an estimate of the uncertainty of the tabulated values is essentially the estimate of the uncertainty of the input data. (We note that the percentage of uncertainty given in table 3 and mentioned here is an assessment of inaccuracy.) For temperatures below 200 K, we assign an uncertainty of ± 3% to the tabulated viscosity values, ± 5% to the tabulated thermal conductivity values. For temperatures above 200 K, the uncertainties are felt to be slightly less: ± 2% and ± 4%, respectively. Close to the critical point, our viscosity values are probably too low by about 5% and our values for the thermal conductivity have an uncertainty of 15%. Extrapolation of the tables is not recommended.

7. Conclusion

A general equation, identical in form for both transport coefficients (excluding the critical point enhancement for the thermal conductivity coefficient), has been used to represent selected viscosity and thermal conductivity data of methane from the dilute gas to the dense liquid. Parameters for the equation were determined by fitting experimental data. Comprehensive tables of transport coefficients are presented.

8. Acknowledgements

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TABLE 5. Tabulated values for the viscosity coefficient of methane. The units for the viscosity are $\mu g/(cm \cdot s)$

	P, MPa									
T, K	0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
95	1793.2									
100	1563.7	1570.3	1578.4	1586.6	1594.8	1603.0	1611.2	1619.4	1627.6	1644.1
105	1377.2	1383.2	1390.6	1398.1	1405.6	1413.1	1420.6	1428.0	1435.5	1450.5
110	1222.9	1228.4	1235.4	1242.3	1249.2	1256.1	1263.0	1269.9	1276.8	1290.5
115	46.0	1098.4	1104.9	1111.4	1117.9	1124.3	1130.8	1137.2	1143.6	1156.4
120	47.9	987.7	993.8	1000.0	1006.1	1012.2	1018.3	1024.4	1030.5	1042.5
125	49.8	892.0	897.9	903.8	909.7	915.6	921.4	927.3	933.1	944.6
130	51.8	808.3	814.1	819.9	825.6	831.3	837.0	842.6	848.3	859.4
135	53.7	734.1	739.9	745.6	751.3	756.9	762.5	768.1	773.6	784.5
140	55.6	56.9	673.3	679.1	684.8	690.5	696.1	701.6	707.1	717.9
145	57.5	58.8	612.9	618.8	624.7	630.4	636.1	641.7	647.2	658.1
150	59.4	60.7	62.6	563.4	569.5	575.5	581.4	587.1	592.8	603.9
155	61.3	62.6	64.4	511.7	518.2	524.5	530.7	536.7	542.7	554.1
160	63.2	64.4	66.2	68.5	469.5	476.4	483.1	489.5	495.9	508.0
165	65.1	66.3	68.0	70.1	422.0	429.9	437.4	444.6	451.5	464.5
170	67.0	68.2	69.8	71.7	74.4	383.4	392.3	400.6	408.4	423.0
175	68.9	70.0	71.6	73.4	75.8	79.2	345.5	355.9	365.4	382.4
180	70.8	71.9	73.3	75.1	77.3	80.2	84.5	306.6	319.8	341.3
185	72.6	73.7	75.1	76.8	78.9	81.5	84.9	90.3	263.0	297.2
190	74.5	75.5	76.9	78.6	80.5	82.8	85.8	89.9	96.5	240.9
195	76.3	77.3	78.7	80.3	82.1	84.3	87.0	90.4	95.1	121.0
200	78.2	79.2	80.5	82.0	83.7	85.8	88.2	91.2	95.0	108.2

	P, MPa									
T, K	6.0	7.0	8.0	9.0	10.0	15.0	20.0	30.0	40.0	50.0
95										
100	1660.5	1677.0	1693.5	1710.0						
105	1465.4	1480.4	1495.3	1510.3	1525.2	1599.7				
110	1304.3	1318.0	1331.7	1345.4	1359.1	1427.0	1494.4			
115	1169.2	1182.0	1194.7	1207.3	1220.0	1282.7	1344.4	1465.2		
120	1054.6	1066.5	1078.5	1090.3	1102.1	1160.5	1217.7	1329.1	1436.1	
125	956.0	967.4	978.7	989.9	1001.1	1056.0	1109.5	1213.1	1312.2	1407.1
130	870.4	881.4	892.2	903.0	913.6	965.8	1016.3	1113.3	1205.7	1294.0
135	795.2	805.9	816.4	826.8	837.1	887.1	935.2	1026.8	1113.6	1196.2
140	728.5	739.0	749.3	759.5	769.5	818.0	864.1	951.3	1033.2	1111.0
145	668.8	679.2	689.4	699.5	709.3	756.7	801.3	884.8	962.7	1036.3
150	614.7	625.2	635.4	645.5	655.3	702.0	745.5	826.0	900.4	970.4
155	565.2	576.0	586.4	596.5	606.4	652.8	695.5	773.6	845.1	912.0
160	519.5	530.7	541.4	551.7	561.7	608.3	650.5	726.6	795.7	859.9
165	476.9	488.5	499.7	510.4	520.7	567.8	609.7	684.4	751.3	813.2
170	436.4	448.9	460.7	471.9	482.6	530.6	572.6	646.1	711.3	771.2
175	397.5	411.2	423.9	435.7	447.0	496.3	538.6	611.4	675.1	733.2
180	359.1	374.6	388.6	401.4	413.4	464.6	507.3	579.6	642.1	698.7
185	320.0	338.5	354.3	368.5	381.4	435.0	478.4	550.5	612.0	667.3
190	277.9	301.6	323.4	336.5	350.7	407.3	451.6	523.8	584.5	638.6
195	226.3	262.3	286.1	304.9	320.9	381.3	426.7	499.1	559.1	612.2
200	157.2	218.1	250.5	273.4	291.8	356.8	403.5	476.2	535.7	588.0

TABLE 5. Tabulated values for the viscosity coefficient of methane. The units for the viscosity are $\mu g/(cm \cdot s)$—Continued

	P, MPa									
T, K	0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
200	78.2	79.2	80.5	82.0	83.7	85.8	88.2	91.2	95.0	108.2
205	80.0	81.0	82.2	83.7	85.4	87.3	89.5	92.2	95.5	105.2
210	81.8	82.7	84.0	85.4	87.0	88.8	90.9	93.4	96.3	104.2
215	83.6	84.5	85.7	87.1	88.6	90.4	92.3	94.6	97.2	104.1
220	85.4	86.3	87.5	88.8	90.3	91.9	93.8	95.9	98.3	104.4
225	87.2	88.1	89.2	90.5	91.9	93.5	95.3	97.3	99.5	105.0
230	89.0	89.8	90.9	92.2	93.6	95.1	96.8	98.7	100.8	105.8
235	90.7	91.6	92.7	93.9	95.2	96.7	98.3	100.1	102.0	106.7
240	92.5	93.3	94.4	95.5	96.8	98.2	99.8	101.5	103.4	107.7
245	94.2	95.0	96.1	97.2	98.5	99.8	101.3	102.9	104.7	108.8
250	95.9	96.7	97.7	98.9	100.1	101.4	102.8	104.4	106.1	109.9
255	97.7	98.4	99.4	100.5	101.7	103.0	104.4	105.9	107.5	111.1
260	99.4	100.1	101.1	102.1	103.3	104.5	105.9	107.3	108.9	112.4
265	101.1	101.8	102.7	103.8	104.9	106.1	107.4	108.8	110.3	113.6
270	102.7	103.5	104.4	105.4	106.5	107.7	108.9	110.3	111.7	114.9
275	104.4	105.1	106.0	107.0	108.1	109.2	110.4	111.7	113.1	116.2
280	106.1	106.8	107.6	108.6	109.7	110.8	111.9	113.2	114.6	117.5
285	107.7	108.4	109.3	110.2	111.2	112.3	113.5	114.7	116.0	118.8
290	109.4	110.0	110.9	111.8	112.8	113.8	115.0	116.2	117.4	120.2
295	111.0	111.6	112.5	113.4	114.3	115.4	116.5	117.6	118.9	121.5
300	112.6	113.2	114.1	114.9	115.9	116.9	118.0	119.1	120.3	122.9
310	115.8	116.4	117.2	118.1	119.0	119.9	120.9	122.0	123.1	125.6
320	119.0	119.5	120.3	121.1	122.0	122.9	123.9	124.9	126.0	128.3
330	122.1	122.6	123.4	124.2	125.0	125.9	126.8	127.8	128.8	131.0
340	125.1	125.7	126.4	127.2	128.0	128.8	129.7	130.6	131.6	133.7
350	128.2	128.7	129.4	130.1	130.9	131.7	132.6	133.5	134.4	136.4
360	131.2	131.7	132.4	133.1	133.8	134.6	135.4	136.3	137.2	139.1
370	134.1	134.7	135.3	136.0	136.7	137.5	138.2	139.1	139.9	141.7
380	137.1	137.6	138.2	138.8	139.5	140.3	141.0	141.8	142.6	144.4
390	140.0	140.4	141.0	141.7	142.4	143.1	143.8	144.6	145.3	147.0
400	142.8	143.3	143.9	144.5	145.1	145.8	146.5	147.3	148.0	149.6
410	145.6	146.1	146.7	147.3	147.9	148.6	149.2	150.0	150.7	152.2
420	148.4	148.9	149.4	150.0	150.6	151.3	151.9	152.6	153.3	154.8
430	151.2	151.6	152.2	152.7	153.3	153.9	154.5	155.3	155.9	157.4
440	153.9	154.3	154.9	155.4	156.0	156.6	157.2	157.9	158.5	159.9
450	156.6	157.0	157.5	158.1	158.6	159.2	159.8	160.5	161.1	162.5
460	159.3	159.7	160.2	160.7	161.3	161.8	162.4	163.0	163.7	165.0
470	161.9	162.3	162.8	163.3	163.9	164.4	165.0	165.6	166.2	167.5
480	164.6	164.9	165.4	165.9	166.4	167.0	167.5	168.1	168.7	169.9
490	167.1	167.5	168.0	168.5	169.0	169.5	170.0	170.6	171.2	172.4
500	169.7	170.1	170.5	171.0	171.5	172.0	172.5	173.1	173.6	174.8

TABLE 5. Tabulated values for the viscosity coefficient of methane. The units for the viscosity are $\mu g/(cm \cdot s)$—Continued

	P, MPa									
T, K	6.0	7.0	8.0	9.0	10.0	15.0	20.0	30.0	50.0	75.0
200	157.2	218.1	250.5	273.4	291.8	356.8				
205	126.1	172.5	213.9	241.9	263.3	333.6				
210	117.7	143.9	180.5	211.8	235.9	311.8	361.5			
215	114.3	131.1	157.1	185.8	213.9	291.4	342.5			
220	112.8	125.2	143.5	166.6	189.9	272.4	324.8			
225	112.2	122.1	135.9	153.8	173.8	255.1	308.3			
230	112.2	120.5	131.6	145.7	162.2	239.5	293.1	369.1		
235	112.5	119.7	129.0	140.5	154.2	225.8	279.2	355.2		
240	113.0	119.5	127.5	137.2	148.7	213.9	266.5	342.3		
245	113.7	119.6	126.6	135.0	144.9	203.9	255.0	330.3		
250	114.5	119.9	126.2	133.7	142.3	195.5	244.8	319.2		
255	115.4	120.4	126.2	132.9	140.5	188.6	235.7	308.9		
260	116.4	121.0	126.4	132.5	139.4	182.9	227.7	299.4		
265	117.4	121.8	126.8	132.4	138.7	178.3	220.7	290.7		
270	118.5	122.7	127.3	132.5	138.3	174.6	214.5	282.6	382.5	
275	119.7	123.6	127.9	132.8	138.1	171.6	209.2	275.3	373.8	
280	120.8	124.5	128.7	133.2	138.2	169.2	204.6	268.6	365.6	
285	122.0	125.6	129.5	133.8	138.5	167.3	200.7	262.5	358.0	
290	123.2	126.6	130.3	134.4	138.8	165.8	197.3	256.9	350.8	
295	124.5	127.7	131.3	135.1	139.3	164.6	194.4	251.9	344.0	
300	125.7	128.8	132.2	135.9	139.9	163.8	191.9	247.3	337.7	
310	128.2	131.1	134.2	137.6	141.3	162.7	188.0	239.4	326.2	
320	130.8	133.5	136.4	139.5	142.8	162.3	185.3	233.0	316.1	
330	133.3	135.9	138.6	141.5	144.6	162.5	183.5	227.8	307.3	388.3
340	135.9	138.3	140.9	143.6	146.5	163.0	182.3	223.6	299.5	378.4
350	138.5	140.8	143.2	145.7	148.4	163.9	181.7	220.3	292.8	369.5
360	141.1	143.2	145.5	147.9	150.5	164.9	181.5	217.7	286.9	361.5
370	143.7	145.7	147.9	150.2	152.6	166.1	181.7	215.7	281.8	354.2
380	146.2	148.2	150.3	152.5	154.7	167.5	182.2	214.1	277.4	347.7
390	148.8	150.7	152.7	154.7	156.9	169.0	182.8	213.1	273.6	341.8
400	151.3	153.1	155.0	157.0	159.1	170.6	183.7	212.3	270.3	336.5
410	153.9	155.6	157.4	159.3	161.3	172.3	184.7	211.9	267.5	331.7
420	156.4	158.1	159.8	161.7	163.6	174.1	185.9	211.8	265.1	327.4
430	158.9	160.5	162.2	164.0	165.8	175.9	187.1	211.9	263.1	323.5
440	161.4	163.0	164.6	166.3	168.0	177.7	188.5	212.1	261.4	320.1
450	163.9	165.4	167.0	168.6	170.3	179.6	189.9	212.6	260.0	317.0
460	166.3	167.8	169.3	170.9	172.5	181.5	191.4	213.2	258.9	314.2
470	168.8	170.2	171.7	173.2	174.8	183.4	193.0	213.9	258.0	311.8
480	171.2	172.6	174.0	175.5	177.0	185.3	194.6	214.7	257.3	309.6
490	173.6	175.0	176.3	177.8	179.2	187.3	196.2	215.6	256.9	307.7
500	176.0	177.3	178.7	180.0	181.5	189.3	197.9	216.7	256.5	306.0

TABLE 6. Tabulated values for the thermal conductivity coefficient of methane. The units are mW/(m·K)

	P, MPa									
T, K	0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
95	215.51									
100	206.19	206.62	207.16	207.69	208.23	208.76	209.29	209.82	210.35	211.41
105	197.31	197.75	198.30	198.86	199.40	199.95	200.50	201.04	201.59	202.67
110	188.80	189.25	189.82	190.39	190.95	191.52	192.08	192.64	193.19	194.30
115	13.58	181.06	181.64	182.23	182.81	183.40	183.97	184.55	185.12	186.26
120	14.14	173.11	173.72	174.33	174.94	175.54	176.14	176.74	177.33	178.51
125	14.70	165.36	166.01	166.65	157.28	157.91	168.53	169.16	169.77	170.99
130	15.26	157.77	158.45	159.13	159.80	160.46	161.12	161.77	162.41	163.69
135	15.82	150.29	151.02	151.74	152.45	153.15	153.85	154.54	155.22	156.56
140	16.38	17.66	143.65	144.43	145.19	145.95	146.69	147.43	148.15	149.58
145	16.94	18.17	136.29	137.14	137.98	138.80	139.60	140.40	141.18	142.70
150	17.49	18.68	20.10	129.83	130.75	131.65	132.54	133.40	134.25	135.90
155	18.05	19.20	20.54	122.38	123.43	124.45	125.43	126.39	127.33	129.14
160	18.60	19.72	21.00	22.51	115.92	117.09	118.21	119.30	120.35	122.36
165	19.15	20.24	21.46	22.85	108.07	109.46	110.78	112.03	113.24	115.52
170	19.70	20.76	21.94	23.23	24.91	101.42	103.02	104.52	105.93	108.56
175	20.25	21.28	22.41	23.63	25.13	27.38	94.92	96.74	98.43	101.48
180	20.80	21.81	22.90	24.05	25.42	27.28	30.47	88.92	90.91	94.44
185	21.35	22.33	23.39	24.49	25.75	27.36	29.73	34.24	84.04	87.80
190	21.90	22.86	23.88	24.93	26.11	27.54	29.47	32.47	38.29	82.03
195	22.45	23.39	24.38	25.39	26.49	27.78	29.43	31.72	35.28	59.45
200	23.01	23.92	24.88	25.85	26.88	28.07	29.51	31.38	33.98	44.24

	P, MPa									
T, K	6.0	7.0	8.0	9.0	10.0	15.0	20.0	30.0	40.0	50.0
95										
100	212.46	213.51	214.56	215.59						
105	203.74	204.81	205.88	206.94	207.99	213.16				
110	195.40	196.50	197.58	198.66	199.74	205.00	210.09			
115	187.39	188.51	189.63	190.73	191.83	197.18	202.34	212.10		
120	179.67	180.83	181.97	183.10	184.22	189.68	194.91	204.78	213.92	
125	172.20	173.39	174.57	175.74	176.89	182.47	187.79	197.77	206.99	215.52
130	164.95	166.19	167.41	168.61	169.80	175.53	180.96	191.07	200.35	208.94
135	157.88	159.17	160.45	161.70	152.93	168.84	174.38	184.64	194.01	202.66
140	150.97	152.33	153.66	154.97	156.26	162.37	168.05	178.48	187.94	196.65
145	144.18	145.63	147.03	148.41	149.76	155.11	161.96	172.57	182.14	190.91
150	137.49	139.04	140.53	141.99	143.41	150.04	156.07	166.90	176.58	185.42
155	130.87	132.53	134.13	135.69	137.19	144.14	150.39	161.46	171.27	180.18
160	124.26	126.08	127.81	129.48	131.09	138.41	144.89	156.23	166.17	175.16
165	117.64	119.64	121.53	123.34	125.07	132.83	139.57	151.21	161.30	170.37
170	110.96	113.19	115.28	117.25	119.12	127.38	134.41	146.37	156.62	165.78
175	104.23	106.73	109.04	111.21	113.24	122.06	129.42	141.72	152.14	161.40
180	97.53	100.32	102.87	105.24	107.45	116.87	124.57	137.25	147.85	157.20
185	91.17	94.18	96.92	99.45	101.82	111.82	119.88	132.94	143.73	153.18
190	85.43	88.58	91.42	94.05	96.50	106.94	115.34	128.79	139.78	149.34
195	79.82	83.48	86.50	89.18	91.66	102.31	110.98	124.81	135.99	145.65
200	68.45	77.54	81.66	84.69	87.28	97.99	106.82	120.98	132.36	142.13

TABLE 6. Tabulated values for the thermal conductivity coefficient of methane. The units are mW/(m·K)—Continued

T, K	P, MPa 0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
200	23.01	23.92	24.88	25.85	26.88	28.07	29.51	31.38	33.98	44.24
205	23.56	24.46	25.39	26.32	27.30	28.40	29.68	31.27	33.32	40.01
210	24.12	25.00	25.91	26.80	27.73	28.75	29.91	31.29	32.99	37.94
215	24.69	25.54	26.42	27.28	28.17	29.12	30.19	31.41	32.86	36.78
220	25.25	26.09	26.95	27.78	28.62	29.52	30.51	31.61	32.87	36.10
225	25.82	26.64	27.48	28.28	29.09	29.94	30.86	31.86	32.98	35.73
230	26.40	27.20	28.02	28.79	29.57	30.38	31.24	32.16	33.17	35.56
235	26.98	27.77	28.56	29.32	30.07	30.84	31.64	32.50	33.43	35.55
240	27.56	28.33	29.11	29.85	30.57	31.31	32.08	32.88	33.74	35.65
245	28.15	28.91	29.67	30.38	31.09	31.80	32.53	33.29	34.09	35.84
250	28.75	29.49	30.24	30.93	31.61	32.30	33.00	33.72	34.48	36.10
255	29.35	30.08	30.81	31.49	32.15	32.82	33.49	34.18	34.89	36.42
260	29.96	30.68	31.39	32.06	32.70	33.34	33.99	34.66	35.34	36.78
265	30.57	31.28	31.98	32.63	33.26	33.88	34.51	35.15	35.81	37.17
270	31.19	31.89	32.58	33.21	33.83	34.44	35.05	35.66	36.29	37.60
275	31.82	32.50	33.18	33.80	34.40	35.00	35.59	36.19	36.80	38.06
280	32.45	33.13	33.79	34.40	34.99	35.57	36.15	36.73	37.32	38.53
285	33.09	33.76	34.41	35.01	35.59	36.15	36.72	37.28	37.86	39.03
290	33.74	34.40	35.04	35.63	36.19	36.75	37.30	37.85	38.41	39.54
295	34.40	35.04	35.68	36.25	36.81	37.35	37.89	38.43	38.97	40.07
300	35.06	35.69	36.32	36.89	37.43	37.96	38.49	39.01	39.54	40.61
310	36.40	37.02	37.63	38.18	38.70	39.21	39.72	40.22	40.72	41.74
320	37.78	38.38	38.97	39.50	40.01	40.50	40.98	41.47	41.95	42.92
330	39.18	39.77	40.34	40.85	41.34	41.82	42.29	42.75	43.22	44.14
340	40.61	41.18	41.74	42.24	42.72	43.18	43.63	44.08	44.52	45.41
350	42.07	42.63	43.17	43.66	44.12	44.57	45.00	45.44	45.87	46.72
360	43.55	44.10	44.63	45.11	45.56	45.99	46.41	46.83	47.25	48.07
370	45.07	45.61	46.12	46.58	47.02	47.44	47.85	48.26	48.66	49.46
380	46.61	47.14	47.64	48.09	48.52	48.93	49.33	49.72	50.11	50.88
390	48.18	48.70	49.19	49.63	50.04	50.44	50.83	51.21	51.59	52.34
400	49.78	50.28	50.76	51.19	51.60	51.99	52.36	52.74	53.10	53.83
410	51.40	51.89	52.36	52.78	53.18	53.56	53.93	54.29	54.64	55.35
420	53.04	53.52	53.99	54.40	54.78	55.15	55.51	55.87	56.22	56.90
430	54.71	55.18	55.64	56.04	56.42	56.78	57.13	57.47	57.81	58.48
440	56.40	56.87	57.31	57.70	58.07	58.43	58.77	59.11	59.44	60.09
450	58.11	58.57	59.01	59.39	59.75	60.10	60.44	60.77	61.09	61.72
460	59.85	60.30	60.72	61.10	61.46	61.80	62.13	62.45	62.76	63.38
470	61.60	62.04	62.46	62.84	63.18	63.52	63.84	64.15	64.46	65.07
480	63.37	63.81	64.22	64.59	64.93	65.26	65.57	65.88	66.18	66.77
490	65.17	65.60	66.00	66.36	66.70	67.02	67.32	67.63	67.92	68.50
500	66.98	67.40	67.80	68.15	68.48	68.79	69.10	69.39	69.68	70.25

TABLE 6. Tabulated values for the thermal conductivity coefficient of methane. The units are mW/(m·K)—Continued

T, K	P, MPa									
	6.0	7.0	8.0	9.0	10.0	15.0	20.0	30.0	50.0	75.0
200	68.45	77.54	81.66	84.69	87.28	97.99				
205	53.48	69.06	75.53	79.35	82.98	94.02				
210	46.33	58.03	67.51	73.82	78.09	90.33	99.22			
215	42.72	51.03	59.78	66.94	72.36	86.75	95.78			
220	40.64	46.73	53.81	60.57	66.38	83.09	92.51			
225	39.36	44.06	49.63	55.48	60.99	79.27	89.34			
230	38.58	42.34	46.80	51.67	56.59	75.35	86.20	101.42		
235	38.12	41.24	44.89	48.94	53.20	71.53	83.08	98.69		
240	37.90	40.55	43.61	47.02	50.68	68.00	80.02	96.08		
245	37.85	40.16	42.78	45.70	48.86	64.90	77.08	93.58		
250	37.92	39.97	42.27	44.82	47.57	62.27	74.36	91.19		
255	38.09	39.95	42.00	44.25	46.69	60.11	71.90	88.92		
260	38.33	40.04	41.90	43.93	46.11	58.37	69.74	86.78		
265	38.64	40.22	41.93	43.78	45.76	56.99	67.87	84.79		
270	38.99	40.47	42.06	43.77	45.58	55.92	66.28	82.96	106.47	
275	39.38	40.78	42.27	43.86	45.54	55.11	64.94	81.29	104.75	
280	39.80	41.13	42.54	44.03	45.60	54.50	63.83	79.79	103.14	
285	40.24	41.52	42.86	44.27	45.75	54.07	62.91	78.44	101.62	
290	40.71	41.94	43.21	44.55	45.95	53.78	62.16	77.24	100.19	
295	41.20	42.38	43.61	44.88	46.21	53.60	61.56	76.18	98.86	
300	41.71	42.85	44.02	45.25	46.52	53.52	61.09	75.24	97.62	
310	42.78	43.84	44.94	46.07	47.23	53.59	60.47	73.71	95.41	
320	43.90	44.90	45.93	46.99	48.07	53.90	60.20	72.58	93.53	
330	45.08	46.03	47.00	47.99	49.00	54.40	60.20	71.79	91.96	112.50
340	46.30	47.21	48.13	49.06	50.02	55.05	60.44	71.30	90.67	110.83
350	47.58	48.44	49.31	50.20	51.10	55.83	60.85	71.06	89.66	109.39
360	48.89	49.72	50.56	51.40	52.26	56.72	61.43	71.04	88.88	108.17
370	50.25	51.04	51.84	52.65	53.47	57.70	62.13	71.22	88.32	107.14
380	51.64	52.41	53.18	53.95	54.73	58.76	62.96	71.56	87.97	106.31
390	53.08	53.81	54.56	55.30	56.05	59.89	63.88	72.05	87.80	105.66
400	54.54	55.26	55.97	56.69	57.41	61.09	64.89	72.66	87.79	105.17
410	56.04	56.73	57.43	58.12	58.81	62.34	65.97	73.40	87.94	104.84
420	57.57	58.25	58.91	59.58	60.26	63.65	67.13	74.24	88.23	104.66
430	59.14	59.79	60.44	61.09	61.73	65.01	68.35	75.16	88.64	104.62
440	60.73	61.36	61.99	62.62	63.25	66.42	69.63	76.18	89.17	104.71
450	62.35	62.96	63.58	64.19	64.80	67.86	70.97	77.26	89.80	104.91
460	63.99	64.59	65.19	65.78	66.38	69.35	72.35	78.42	90.53	105.23
470	65.66	66.25	66.83	67.41	67.98	70.87	73.77	79.64	91.35	105.65
480	67.35	67.93	68.49	69.06	69.62	72.42	75.24	80.91	92.26	106.17
490	69.07	69.63	70.18	70.73	71.28	74.01	76.74	82.24	93.23	106.78
500	70.81	71.35	71.90	72.43	72.97	75.63	78.28	83.61	94.28	107.47

TABLE 7. Transport coefficients of saturated liquid methane.

Temperature, K	Density, mol/l	Viscosity, $\mu g/(cm \cdot s)$	Thermal conductivity, $mW/(m \cdot K)$
95	27.789	1792	215
100	27.367	1563	206
105	26.934	1377	197
110	26.491	1223	189
115	26.035	1094	181
120	25.566	984	173
125	25.081	889	165
130	24.578	807	158
135	24.055	734	150
140	23.508	669	143
145	22.932	611	136
150	22.322	558	129
155	21.672	509	122
160	20.971	464	115
165	20.206	421	108
170	19.356	380	101
175	18.386	340	94
180	17.226	300	88
185	15.690	256	84
190	12.485	187	89

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Appendix

Methane Equation of State

The equation of state used in the work is that reported by McCarty in reference [5]. The form of the equation. and its parameters are reproduced in this appendix.

The equation of state is given by the following functional form:

$$
\begin{aligned}
P = \rho RT &+ \rho^2 (N_1T + N_2T^{1/2} + N_3 + N_4/T + N_5T^2) \\
&+ \rho^3 (N_6T + N_7 + N_8/T + N_9/T^2) \\
&+ \rho^4 (N_{10}T + N_{11} + N_{12}/T) + \rho^5 (N_{13}) \\
&+ \rho^6 (N_{14}/T + N_{15}/T^2) + \rho^7 (N_{16}T) \\
&+ \rho^8 (N_{17}/T + N_{18}/T^2) + \rho^9 (N_{19}T^2) \\
&+ \rho^3 (N_{20}/T^2 + N_{21}/T^3) \exp(-\gamma\rho^2) \\
&+ \rho^5 (N_{22}/T^2 + N_{23}/T^4) \exp(-\gamma\rho^2) \\
&+ \rho^7 (N_{24}/T^2 + N_{25}/T^3) \exp(-\gamma\rho^2) \\
&+ \rho^9 (N_{26}/T^2 + N_{27}/T^4) \exp(-\gamma\rho^2) \\
&+ \rho^{11} (N_{28}/T^2 + N_{29}/T^3) \exp(-\gamma\rho^2) \\
&+ \rho^{13} (N_{30}/T^2 + N_{31}/T^3 + N_{32}/T^4) \exp(-\gamma\rho^2)
\end{aligned}
$$

where, to be consistent with reference [5], P is in atmospheres, ρ is in mol/l, and T is in kelvins.

The coefficients are

$$
\begin{aligned}
N_1 &= -1.8439486666 \times 10^{-2} \\
N_2 &= 1.0510162064 \\
N_3 &= -1.6057820303 \times 10 \\
N_4 &= 8.4844027562 \times 10^{2} \\
N_5 &= -4.2738409106 \times 10^{4} \\
N_6 &= 7.6565285254 \times 10^{-4} \\
N_7 &= -4.8360724197 \times 10^{-1} \\
N_8 &= 8.5195473835 \times 10 \\
N_9 &= -1.6607434721 \times 10^{4} \\
N_{10} &= -3.7521074532 \times 10^{-5} \\
N_{11} &= 2.8616309259 \times 10^{-2} \\
N_{12} &= -2.8685285973 \\
N_{13} &= 1.1906973942 \times 10^{-4} \\
N_{14} &= -8.5315715699 \times 10^{-3} \\
N_{15} &= 3.8365063841 \\
N_{16} &= 2.4986828379 \times 10^{-5} \\
N_{17} &= 5.7974531455 \times 10^{-6} \\
N_{18} &= -7.1648329297 \times 10^{-3} \\
N_{19} &= 1.2577853784 \times 10^{-4} \\
N_{20} &= 2.2240102466 \times 10^{4} \\
N_{21} &= -1.4800512328 \times 10^{6} \\
N_{22} &= 5.0498054887 \times 10 \\
N_{23} &= 1.6428375992 \times 10^{6} \\
N_{24} &= 2.1325387196 \times 10^{-1} \\
N_{25} &= 3.7791273422 \times 10 \\
N_{26} &= -1.1857016815 \times 10^{-5} \\
N_{27} &= -3.1630780767 \times 10 \\
N_{28} &= -4.1006782941 \times 10^{-6} \\
N_{29} &= 1.4870043284 \times 10^{-3} \\
N_{30} &= 3.1512261532 \times 10^{-9} \\
N_{31} &= -2.1670774745 \times 10^{-6} \\
N_{32} &= 2.4000551079 \times 10^{-5} \\
\gamma &= 0.0096 \\
R &= 0.08205616
\end{aligned}
$$

Errata

Erratum: Atomic Form Factors, Incoherent Scattering Functions, and Photon Scattering Cross Sections

[J. Phys. Chem. Ref. Data 4, 471 (1975)]

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P. 495: In TABLE I. Atomic form factor, $F(x, Z)$, and incoherent scattering function, $S(x, Z)$, the values for $S(x, Z)$ for 2 He (helium) for $x = 0.005$ through 0.02 Å^{-1} should be replaced as follows:

2 He

x, Sin(theta/2) /lambda	$S(x, Z)$ (Previous values)	$S(x, Z)$ (Corrected values)
5.00−03	2.1000−03	8.3186−04
1.00−02	5.0000−03	3.3274−03
1.50−02	8.8000−03	7.4867−03
2.00−02	1.4100−02	1.3310−02

These corrected values take advantage of the asymptotic form of $S(x, Z)$ for small x [1]:

$$S(x, Z) = [M(Z)]^2 \cdot (4\pi a_0 x)^2, \; x \ll 1, \qquad (1)$$

given implicitly by Inokuti [2] (his equations 3.17 and 3.18), in which a_0 is the first Bohr radius 0.52917706 Å and $M(Z)$ is the total dipole-matrix-element. To obtain the above helium $S(x, Z)$ values for small x from the above eq (1) we used, as suggested by Gillespie [1], the value $[M(\text{He})]^2 = 0.752497553$ calculated by Pekeris [3] (the quantity denoted $S(-1)$ in his Table II).

The above corrected $S(x, Z)$ values are in good agreement with the comparable values of $S(x, Z)$ for helium:

x, sin $(\theta/2)/\lambda$(Å)	$S(x, Z)$ (Smith et al. [4])
5.00−03	8.376−04
1.00−02	3.347−03
1.50−02	7.521−03
2.00−02	1.334−02

obtained from the recent Smith et al. [4] analytic approximation

$$S(x, Z) \simeq Z[1-(1+ax^2+bx^4)(1+cx^2+dx^4)^{-2}], \quad 0 \leq x \leq \infty, \qquad (2)$$

which has the correct asymptotic behavior for small [5] as well as large [6] values of x, and in which a, b, c, and d are Z-dependent fitted parameters tabulated in reference [4] for all Z's 2 to 95.

P. 496: Also in TABLE I, the value of $S(x, Z)$ for 6 C (carbon) for $x = 0.04$ should be replaced as follows:

6 C

x, Sin(theta/2 /lambda	$S(x, Z)$ (Previous value)	$S(x, Z)$ (Corrected value)
4.00−02	2.015−02	2.015−01

P. 515: In TABLE II. Coherent and incoherent scattering cross sections, barns/atom, the values of the incoherent scattering cross section "INCOH" for 2 He

(helium) for photon energies 100 to 1000 eV should be replaced as follows:

Photon energy eV	INCOH (Previous values)	INCOH (Corrected values)
1.0+02	1.524−03	7.194−04
1.5+02	2.559−03	1.618−03
2.0+02	3.793−03	2.876−03
3.0+02	7.081−03	6.438−03
4.0+02	1.183−02	1.144−02
5.0+02	1.796−02	1.768−02
6.0+02	2.543−02	2.523−02
8.0+02	4.426−02	4.413−02
1.0+03	6.767−02	6.759−02

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