The Viscosity and Thermal Conductivity Coefficients of Dilute Argon, Krypton, and Xenon

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The viscosity and thermal conductivity coefficients of dilute argon, krypton, and xenon are reviewed and tables of recommended values presented. The tables were generated using the appropriate kinetic theory expressions with the m–6–8 potential. The temperature range covers from about one-half critical temperature to 2000 K for each gas. A general estimate of the accuracy is one percent increasing to one and three-quarters percent for temperatures above 1000 K.

Key words: Dilute gas; kinetic theory; m–6–8 potential function; rare gases; thermal conductivity coefficient; viscosity coefficient.

1. Introduction

In this paper the dilute gas transport properties of the gases argon, krypton, and xenon are discussed and tabulated values of the viscosity and thermal conductivity coefficients presented. The temperature region covered ranges from about one-half critical temperature to 2000 K for each gas.

The tables are based strongly on data which have become available in the last six years or so. On experimental grounds these data are judged to be generally more reliable than corresponding data produced prior to that time. Further, the tables were generated by combining kinetic theory with the data leading to a consistent representation of both the viscosity and thermal conductivity coefficients for a given gas. Moreover, kinetic theory enables one to verify that these coefficients are compatible with other transport properties—the diffusion coefficient and the thermal diffusion factor—and with equilibrium properties via the second virial coefficient.

2. Experimental Methods and Data

Experimental techniques will not be discussed in this paper. Some general references are: viscosity, the article by Bruges and Whitelaw [1][1] and the references therein, and the older book of Barr [2]; thermal conductivity, the two volumes edited by Tye [3], which contain several articles on experimental techniques and numerous references. Reference should also be made to the books of Golubev on viscosity [4], and of Vargaftik [5] and Tsederberg [6] on thermal conductivity. Discussions on recent experimental procedures include those given by Kestin [7, 8] for viscosity and by McLaughlin [9] for thermal conductivity.

However, there are three remarks:

1. Most of the viscosity data for the common gases have been obtained from one of two procedures known as the capillary flow and oscillating disc methods, respectively. However, prior to about 1968, apparently self-consistent measurements obtained from the former technique tended to differ systematically from corresponding measurements obtained from the latter. The discrepancies were most noticeable at temperatures above 400 K.[2] For this reason, an evaluation of viscosity data was inconclusive. But since about 1968, several authors have re-examined the capillary flow technique [8, 13, 14] and new results have been published [13–17] which are consistent with the results from the oscillating disc. On this basis, the general conclusion is that many of the older capillary flow viscosity data were incorrect; this conclusion is reinforced by studies on the intermolecular potential function [10] and, to a lesser extent, by a re-evaluation of some of the older experiments [18].

2. Most of the methods that measure the thermal conductivity coefficient are based on setting up a steady state condition in the fluid, viz., a constant known heat flux is maintained at one boundary of the initially isothermal fluid and the resultant temperature gradient measured after reaching the steady state. The several techniques which employ the steady state are generally designated the parallel plate, concentric cylinders, and hot wire methods. We refer to reference [3] for discussions on these approaches. However, the drawback to the procedure is that convection (and to a lesser extent radiation) contributions, have to be properly accounted for, which is a very difficult experimental problem. Consequently, many of the sets of thermal conductivity data available for a particular gas disagree by amounts outside the experimental errors quoted by the authors concerned, and even sets from a particular author are often not internally consistent. In short, on experimental grounds, we are presently unable to set the reliability of the majority of thermal conductivity data at less than five percent.[3]

[1] Numbers in brackets refer to the references.

[2] For example, we compared [10] the capillary flow viscosities of Trautz and co-workers [11], with equivalent oscillating disc data from Kestin [12b] and concluded that the viscosity coefficients could differ by as much as ten percent at 2000 K.

[3] Several papers have recently been published which describe a non-stationary state (transient) method. For example, see the work of Mani and Vernart [19], Haarman [20], Davis, et al. [21], and McLaughlin and Pittman [9]. These authors discuss the determination of the thermal conductivity coefficient by measuring the temperature rise in a thin suspended wire from the time a current is passed through the wire. The concept is not new but the recent advances result from modern technology which, in particular, allows for the accurate measurement of a small temperature rise within a fraction of a second after the heating current is applied. It seems the transient hot wire technique is capable of giving accurate results although only Haarman [20] has given results of direct relevance to this paper.

3. It will be shown in section 3 that kinetic theory gives a very simple relation between the viscosity and thermal conductivity coefficients of a dilute monatomic gas: given the viscosity coefficient one can calculate the thermal conductivity coefficient directly. For this reason, thermal conductivity data are not required as primary input but are needed only to check on the consistency of the correlating procedure.

In view of the above remarks, our correlation is based on the viscosity data and strongly weighted to favor the viscosity results published since about 1968. A concerted attempt was made to estimate accuracy and reliability of the data from an objective evaluation of the experimental papers helped by discussions with the authors and observations of the apparatus for as many sources as possible. References for the measurements selected are listed in table 1.[4] General lists of experimental sources are given in references [30–32].

Thermal conductivity references are also presented in table 1. As remarked above, it is not possible to be as selective on experimental grounds with the thermal conductivity data as one could like. The data from references [20], [26], and [37] are judged to be the most reliable but we have no strong reason to exclude any of the data from the other references listed. Other experimental references can be found in references [30], [31], and [50].

3. Kinetic Theory Equations

The Dilute Gas: A dilute gas is a gas whose physical properties can be completely described in terms of uncorrelated binary collisions between its molecules; three body or higher order collisions do not contribute to its properties. One characteristic of a dilute gas is that the viscosity and thermal conductivity coefficients are independent of density or pressure.

The kinetic theory equation for the viscosity of a dilute gas is, to a second approximation [51]:

$$\eta=\frac{5}{16}\frac{(\pi mkT)^{1/2}}{\pi\sigma^2\Omega^{(2,2)*}}f_\eta, \tag{1}$$

where

$$f_\eta=1+\frac{3}{196}\left(8\frac{\Omega^{(2,3)*}}{\Omega^{(2,2)*}}-7\right)^2. \tag{2}$$

Here T is the temperature in kelvin, and the quantities $\Omega^{(l,s)*}$ (in general; l, $s=1$, 2, 3) are dimensionless collision integrals which take into account the dynamics of a binary collision and are characteristic of the intermolecular potential of the colliding molecules. For a given potential, $\Phi(r)$, with an energy parameter ϵ (defined as the value of $\Phi(r)$ at the maximum energy of attraction) $\Omega^{(l,s)*}$ can be determined as a function of reduced temperature T^*

$$T^*=T/(\epsilon/k). \tag{3}$$

The parameter σ is a distance parameter, also characteristic of the intermolecular potential given by $\Phi(\sigma)=0$.

The specific relationship between $\Omega^{(l,s)*}$ and $\Phi(r)$ is as follows. A parameter g^* is defined as the reduced relative kinetic energy of two colliding molecules: $g^{*2}=1/2\,(\mu g^2/\epsilon)$, where μ is the reduced mass, and g the relative velocity. A parameter b is defined as the distance of one molecule from the direction of approach of another before collision.

With r the intermolecular separation and r_c the distance when the molecules are closest, we can show that the angle of scatter, χ, after a collision is related to the potential by

$$\chi=\pi-2b^*\int_{r_c^*}^{\infty}dr^*/r^{*2}\left[1-\frac{b^{*2}}{r^{*2}}-\frac{\Phi^*}{g^{*2}}\right]^{-1/2}, \tag{4}$$

where the variables are reduced according to the relations: $b^*=b/\sigma$, $r^*=r/\sigma$, $r_c^*=r_c/\sigma$, $\Phi^*=\Phi/\epsilon$. Integration of χ over all values of b^* produces the cross section, Q^*,

$$Q^{(l)*}=\frac{2}{\left[1-\frac{1}{2}\frac{(+(-1)^l)}{1+e}\right]}\int_0^{\infty}(1-\cos^l\chi)b^*db^*. \tag{5}$$

($Q^{(l)*}$ is dimensionless and has been reduced by the corresponding value for molecules interacting with a hard sphere potential.) Finally, $\Omega^{(2,2)*}$ is obtained by integration of Q over all values of g^*,

$$\Omega^{(l,s)*}(T^*)=\frac{2}{(s+1)!\,T^{*(s+2)}}\int_0^{\infty}\exp(-g^{*2}/T^*)g^{*(2s+3)}Q^{(l)*}(g^*)dg^*. \tag{6}$$

For a dilute monatomic gas, the thermal conductivity coefficient is related to the viscosity by the expression

$$\lambda=\frac{15}{4}\frac{k}{m}\eta f_\lambda/f_\eta \tag{7}$$

where

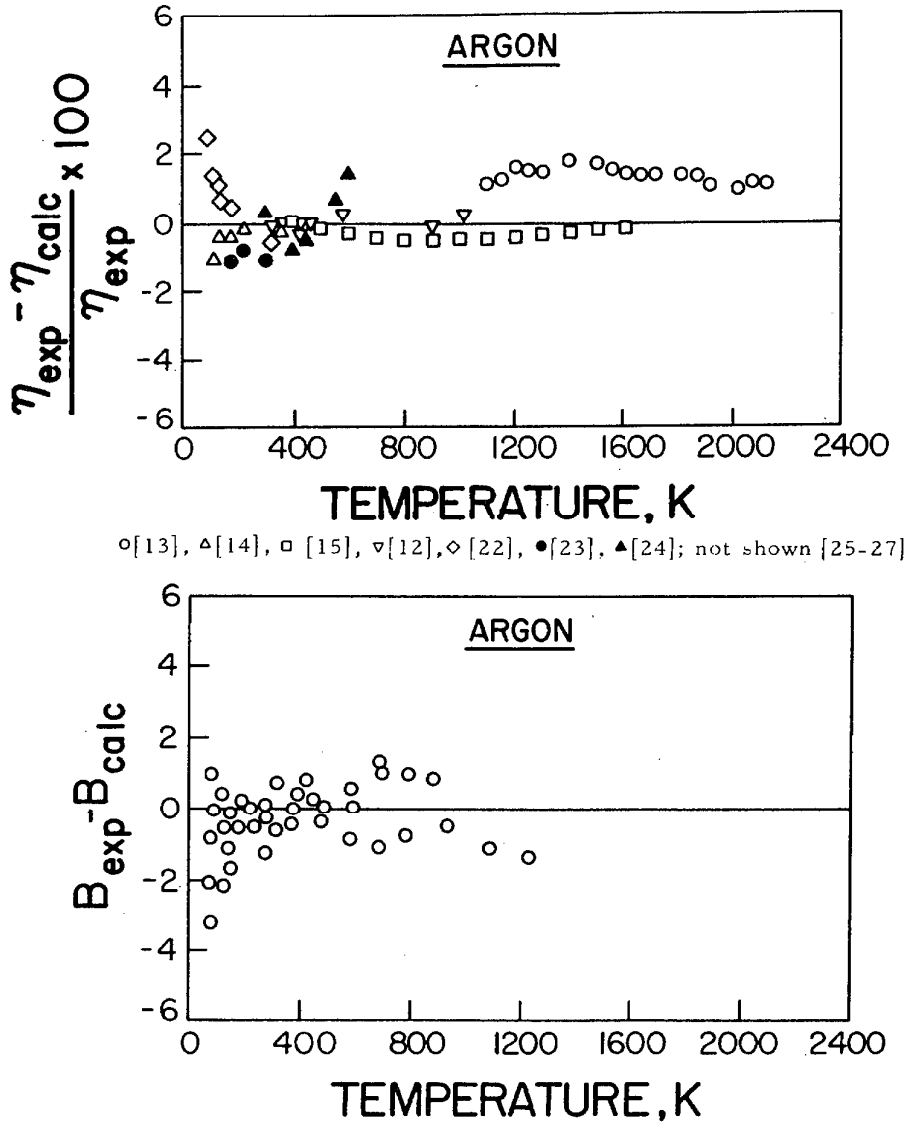
$$f_\lambda=1+\frac{1}{42}\left(8\frac{\Omega^{(2,3)*}}{\Omega^{(2,2)*}}-7\right)^2 \tag{8}$$

For the purposes of this paper we do not have to discuss how equations (1) and (7) were derived or the necessary background assumptions [52].

3.1. Calculation Procedure

Correct use of equations (1) and (7) resolves into the problem of properly selecting a model for the intermolecular potential function for insertion into the collision integral expressions via equation (4). Hanley and Klein have discussed such a selection process [53]

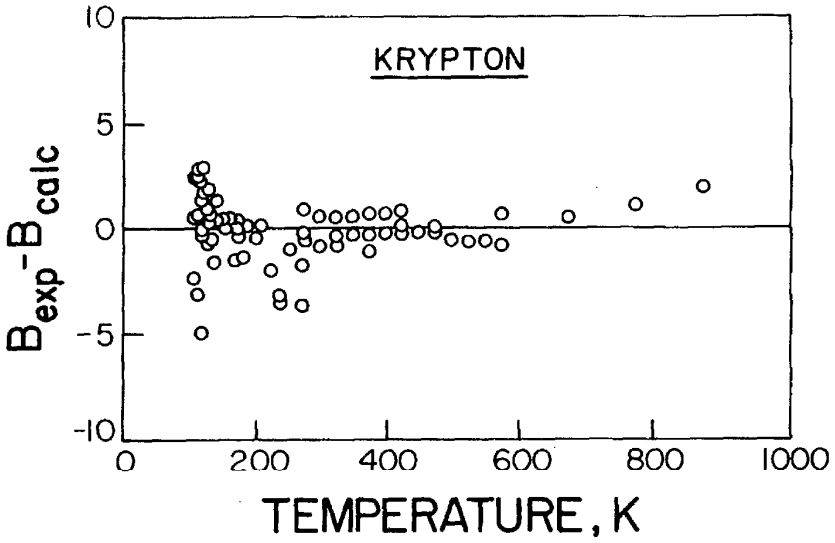
[4] Tables have been placed at the end of this paper.

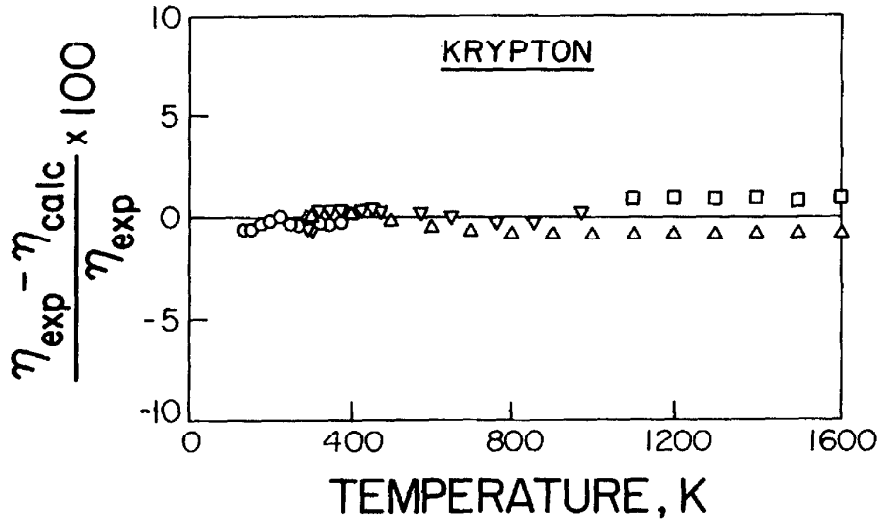


○[13], △[14], □ [15], ▽[12], ◇ [22], ●[23], ▲[24]; not shown [25-27]

FIGURE 1. Top drawing: percentage deviation plot between experimental dilute gas viscosity coefficients for argon and values calculated from equation (1) with the m–6–8 potential: $m=11$, $\gamma=3.0$, $\sigma=3.297$ Å and $\epsilon/k=152.8$ K.

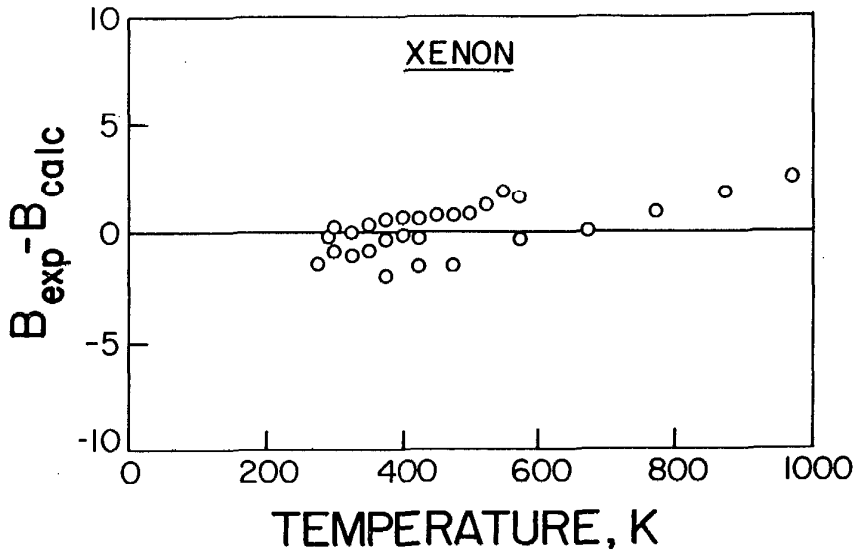
Bottom drawing: Deviations between the virial coefficients of argon [57] in cm^3/mol compared to values from equation (9) using the same m–6–8 parameters.

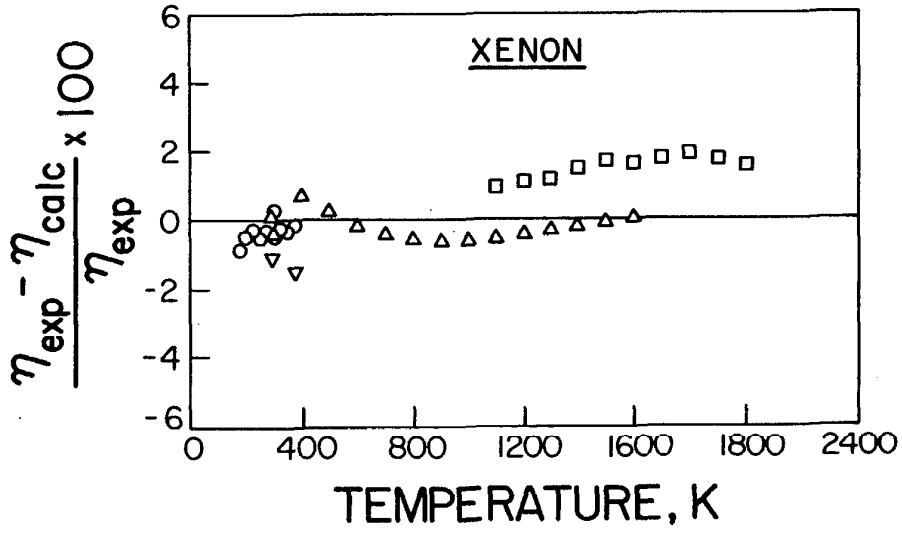




o[14], Δ[15], ▽[12], □[16]

FIGURE 2. Deviation curves for the viscosity and second virial coefficients of krypton. Theoretical values determined for equations (1) and (9) with the m–6–8 potential, parameters as given in table 2.





○[14], △[15], □[17], ▽[28, 29]

FIGURE 3. Deviation curves for the viscosity and second virial coefficients of xenon. See table 2.

and various models have been compared and contrasted (for example, see reference [54]). A particular model, called the m–6–8, was proposed [55] and shown to be successful and practical when used to relate statistical mechanical expressions, such as equations (1) and (7), with experiment. In this paper, we will calculate the dilute gas transport properties with the m–6–8 potential.

The m–6–8 potential has the form:

$$\Phi^* = \frac{1}{m-6}\,[6+2\gamma]\left(\frac{d}{r^*}\right)^m - \frac{1}{m-6}\,[m-\gamma\,(m-8)]\left(\frac{d}{r^*}\right)^6 - \gamma\left(\frac{d}{r^*}\right)^8, \qquad (9)$$

where $d=r_m/\sigma$ with $\Phi(r_m)=-\epsilon$ (or $d\,\Phi(r_m)/dr=0$). m and γ are parameters representing the repulsion and the attraction due to a $1/r^8$ term, respectively. In reference [55] we have described in detail how the parameters m, γ, σ (or r_m), and ϵ of equation (8) are determined for a given fluid. Essentially, the viscosity and second virial coefficients (B) in the low temperature region (defined as temperatures for which $T^* \lesssim 2$) are fitted simultaneously to equation (1) and to the equivalent statistical mechanical expression for B:

$$B=\frac{2}{3}\pi N\sigma^3 \int_0^\infty r^{*3}\frac{d\Phi^*}{dr^*}\exp\,[-\Phi^*/T^*]\,dr^*, \qquad (9)$$

or

$$B=\frac{2}{3}\,\pi N\sigma^3\,B^*\,(T^*), \qquad (9a)$$

where N is Avagadro's number. Tables of $\Omega^{(2,2)*}$ and B^* for several values of m and γ have been published in reference [56]. We have discussed the selection of the viscosity data in section 2. Second virial data were selected carefully by Klein and Levelt Sengers [57].

Parameters obtained from this simultaneous fit were checked by fitting the viscosity coefficient over a wide temperature range. Clearly, if the data are reliable and the potential function sufficiently flexible, the parameters required for a wide temperature range fit of the viscosity coefficient should be those found from the simultaneous fit. This was the case for argon, krypton, and xenon. Parameters for these gases are listed in table 2. Collision integrals and second virial coefficients presented in reference [56] are reproduced here in an appendix.

Having a potential which can properly calculate the viscosity from equation (1), the thermal conductivity coefficient follows from equation (7).

4. Results and Discussion

Tables for the viscosity and thermal conductivity coefficients for argon, krypton, and xenon were generated from equations (1) and (7) as a function of temperature and presented as tables 3 to 5. Figures 1 to 3 show deviation plots between the selected viscosity data and corresponding tabulated values together with second virial difference plots between experiment and values calculated from equation (9).

In our opinion a proper correlation of the viscosity coefficient has been achieved: the only feature shown in the curves which is not satisfactory is that the two sets of high temperature viscosity data—due to Smith and co-workers and to Guevara and co-workers—differ systematically by about one and three quarters percent. This difference cannot be properly accounted for by using an identical reference viscosity. We cannot prefer one set over the other on experimental grounds but our correlation tends to favor the Smith data. It should be recalled that the high temperature viscosity correlation is largely based on a correlation of *low* temperature viscosity data and the second virial coefficient. The low temperature correlation gives a potential function, and the high temperature data were used to check on the parameters selected.

Figures 4 to 6 illustrate the deviations between our calculations and experiment for the thermal conductivity coefficient. Considering the scatter in the data, ascribed to experimental problems (section 2), the curves are satisfactory and reinforce the opinion that our correlation procedure is sound. As discussed, thermal conductivity data played no role in the parameter selection of the potential function.

4.1. Accuracy Assessment

In general there are two ways by which one can assess the accuracy of the tabulated values:

1. From *experimental* arguments, that is by attempting to judge the accuracy of the data on which the tables are based by evaluating the experimental procedures, by checking the internal consistency of the data resulting from a particular experiment, and by intercomparing equivalent data obtained from different authors, giving special weight to comparisons between results from different techniques.
2. From *semi-theoretical* arguments, that is by examining how well the potential required to generate the viscosity and thermal conductivity coefficients can represent independent properties, given the appropriate statistical mechanical expressions. If the potential is satisfactory in this context, one can conclude that the transport tables are consistent with other properties and that serious systematic errors are most likely absent. It would be improbable that any systematic errors in the data for different properties, together with the inexactness of the potential model, would fortuitously cancel.

1. To discuss the first approach: such arguments are basic to the correlation procedure and have been already invoked since our correlation is based on *selected* data (section 2). However, in section 3 and above in this section, it was pointed out that the correlations were especially dependent on a proper fit of viscosity data at

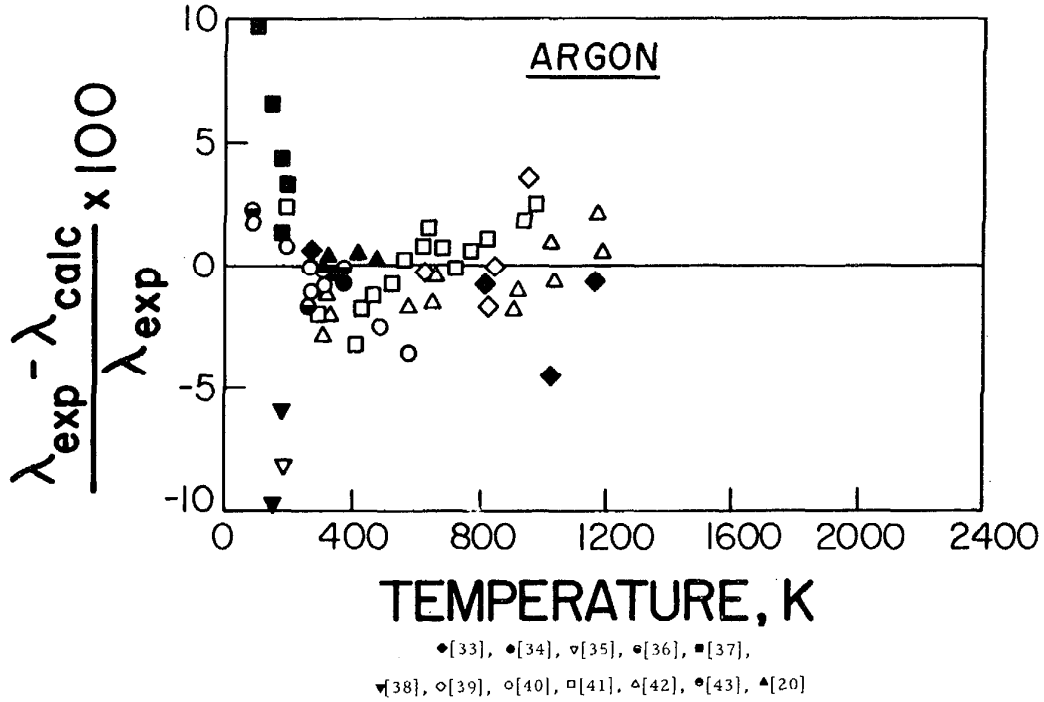


FIGURE 4. Percentage deviation plot of experimental dilute gas thermal conductivity coefficients for argon compared to equation (7) with the m–6–8 potential.

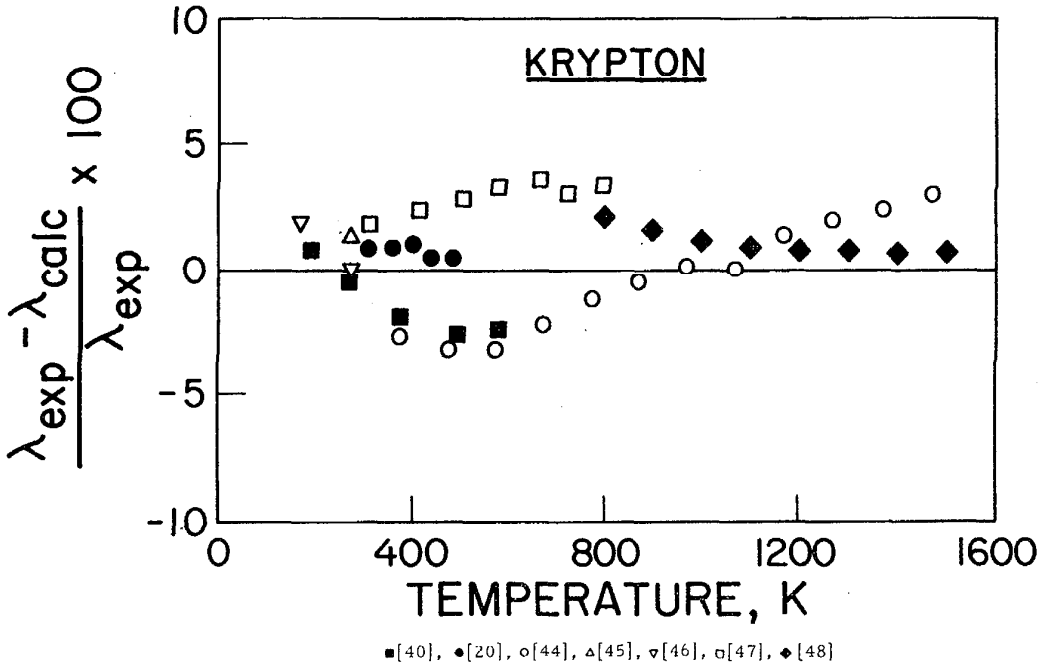


FIGURE 5. Deviation curve for the thermal conductivity of krypton. Theoretical values calculated from equation (7) with parameters given in table 2.

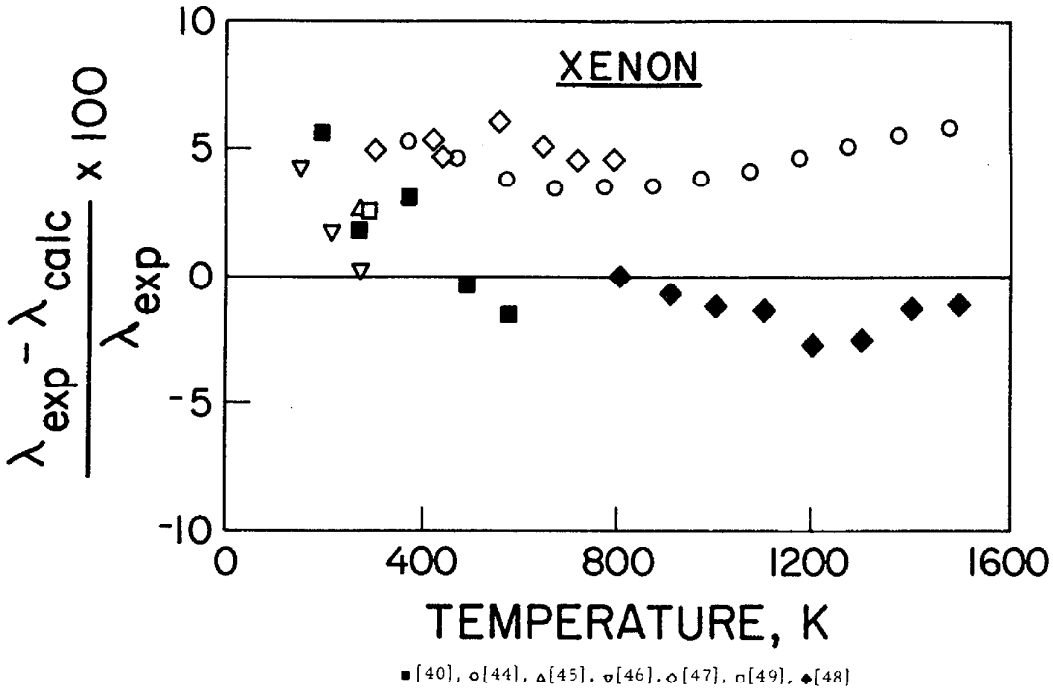


FIGURE 6. Deviation curve for the thermal conductivity of xenon. Theoretical values calculated from equation (7) with parameters given in table 2.

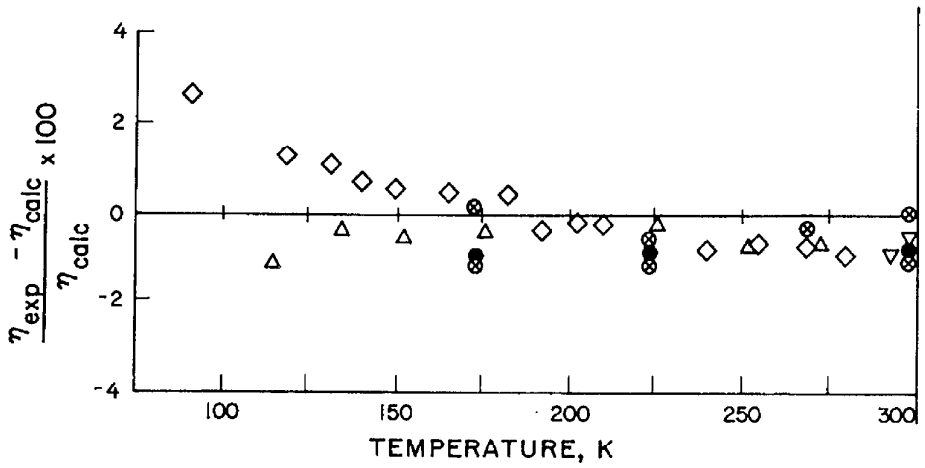


FIGURE 7. Comparison between several sets of viscosity data for argon, including that recently measured by Haynes (crossed circles). The base line was calculated from the 11–6–8 potential as in figure 1 (key as in fig. 1).

low temperatures. A further accuracy assessment can be made by examining such data in more detail.

Let us consider argon only because much of the data for all three gases, argon, krypton, and xenon, were obtained from the same sources. Figure 7 expands figure 1 and plots deviations between experimental viscosity coefficients and the tabulated values. Five data sets are represented: Kestin [12], Johnston [22], Clark [14], Gracki [23], and the very recent data of Haynes [27]. The figure indicates that these data sets lie within about one percent of each other above 120 K and are within one percent of our correlation; on the basis of an examination of these experimental papers, we assigned accuracies to the data as follows: [12], 0.5 percent; [22] and [27], 2 percent; [14] and [23], 1 percent. Moreover, the sets represent three different experimental procedures, the oscillating disc [12, 22], the capillary flow [14, 23], and the oscillating crystal [27]. We therefore conclude that one percent is a fair estimate of uncertainty for our representation.

It could be argued that a one percent estimate is too conservative for the data around room temperature and that our correlated values are too high. At these temperatures, extremely precise results have been reported; Kestin, et al. [12b], for example, quote a precision of their experimental viscosity coefficient at 298.15 of 0.2 percent. (The accuracy of this datum point is not necessarily so well defined.)

However, by examining data for a wide temperature range for all three gases, shown in figures 1–3 and 7 (and figures 4–6 for the thermal conductivity coefficient) we suggest that an overall accuracy estimate of ±1 percent for the viscosity coefficient in the temperature range 100–1000 K properly reflects the accuracy in the data and that our tables, for both transport coefficients, reflect this estimate. Giving equal weight to the low temperature data of references [14] and [22] and to the high temperature data of references [15] and [13, 16, 17], the estimate could be increased to ± 2 percent below 100 K and to ±1¾ percent above 1000 K.

2. The second approach supplements the first. In fact, it has been directly applied because second virial coefficient data were required to assist in the selection of m–6–8 potential parameters used to generate the viscosity and thermal conductivity coefficients. Figures 1–3 reveal that the fits of experimental virial coefficients are excellent. Even though the m–6–8 is not, of course, an exact representation of the intermolecular interactions for the rare gases, and the virial data clearly are not error free, one has to conclude from figures 1–3 that the viscosity coefficients and second virial coefficients are consistent.

It has been discussed in reference [55] that the m–6–8 potential also leads to a satisfactory and consistent representation of the self-diffusion coefficient and the isotopic thermal diffusion factor for argon, krypton, and xenon. Given the parameters of table 2, comparisons between theory and experiment for these properties are presented here. The statistical mechanical equations are:

Thermal Diffusion Factor, α_0

Kihara's [55] equation for α_0 is

$$\alpha_0 = \alpha_0' \, (1 + \delta), \tag{10}$$

where

$$\alpha_0' = \frac{15 \, (6C^* - 5) \, (2A^* + 5)}{2A^* \, (16A^* - 12B^* + 55)}, \tag{11}$$

with δ given by

$$\delta = \frac{I^*}{9}\left\{\frac{2A^*}{(35/4) + 7A^* + 4F^*} \times \left[H^* + \frac{1}{2}\left(\frac{7(5 - 6C^*) + A^*I^*}{5 + 2A^*}\right) \times \left(\frac{(35/8) + 28A^* - 6F^*}{21A^*}\right)\right] - \frac{5}{7}\left[II^* - \frac{7}{5}\left(\frac{5 - 6C^*}{5 + 2A^*}\right) - \frac{3I^*}{10}\right]\right\}, \tag{12}$$

where

$$I^* = 7 - 8E^*, \tag{13}$$

and

$$H^* = \frac{(35/4 - 3B^* - 6C^*)}{5 - 6C^*}. \tag{14}$$

The potential function enters into the equation for α_0 through the ratios of collision integrals A^*, B^*, C^*, E^*, and F^*:

$$\begin{aligned} A^* &= \Omega^{(2,2)*}/\Omega^{(1,1)*}, \\ B^* &= (5\Omega^{(1,2)*} - 4\Omega^{(1,3)*})/\Omega^{(1,1)*}, \\ C^* &= \Omega^{(1,2)*}/\Omega^{(1,1)*}, \\ E^* &= \Omega^{(2,3)*}/\Omega^{(2,2)*}, \\ F^* &= \Omega^{(3,3)*}/\Omega^{(1,1)*}. \end{aligned} \tag{15}$$

Self-diffusion Coefficient, D

The equation for the self-diffusion coefficient is:

$$\rho D = \frac{5}{8}\frac{(\pi mkT)^{1/2}}{\pi\sigma^2 \, \Omega^{(1,1)*}} f_D, \tag{16}$$

where

$$f_D = 1 + (6C^* - 5)^2/(16A^* + 40), \tag{17}$$

and ρ is the mass density.

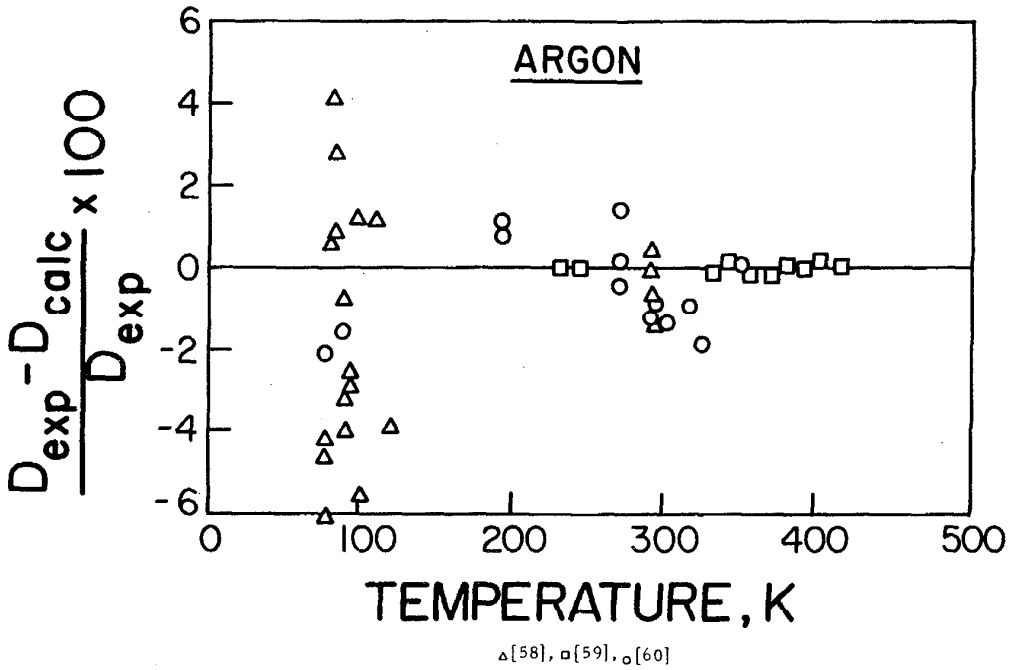


FIGURE 8. Comparison between experimental self-diffusion coefficients of argon and to theoretical values determined from equation (16) with the m–6–8 potential using the same parameters required by the viscosity and second virial coefficients. *Note:* the data from [59] are relative to D at 298.15 K. We used the calculated value for this reference point.

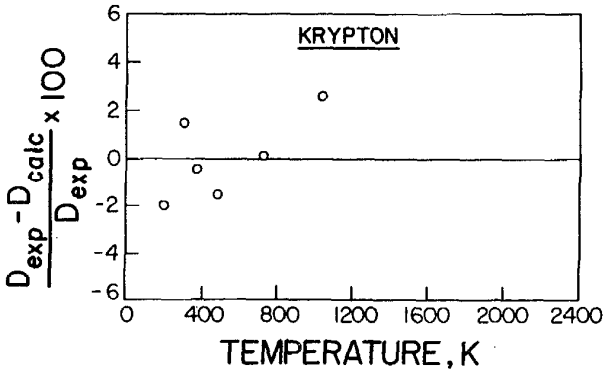


FIGURE 9. Deviation curve for the self-diffusion coefficient of krypton from equation (16) with the parameters given in table 2, experiment from [60].

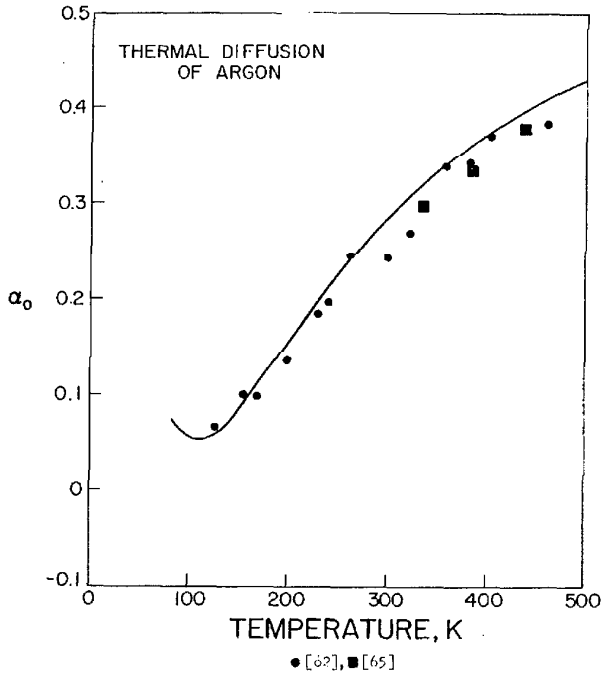


FIGURE 10. Experimental and theoretical (equation (10)) thermal diffusion factors for argon. We use the same m–6–8 potential as for the other transport coefficients.

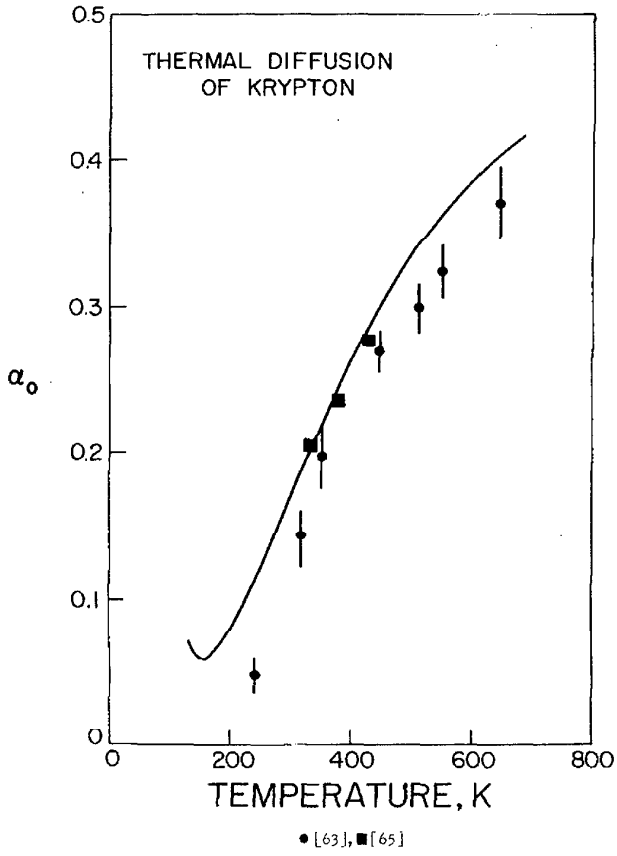


FIGURE 11. The isotopic thermal diffusion factor for krypton calculated from equation (10), using parameters given in table 2, compared to experiment.

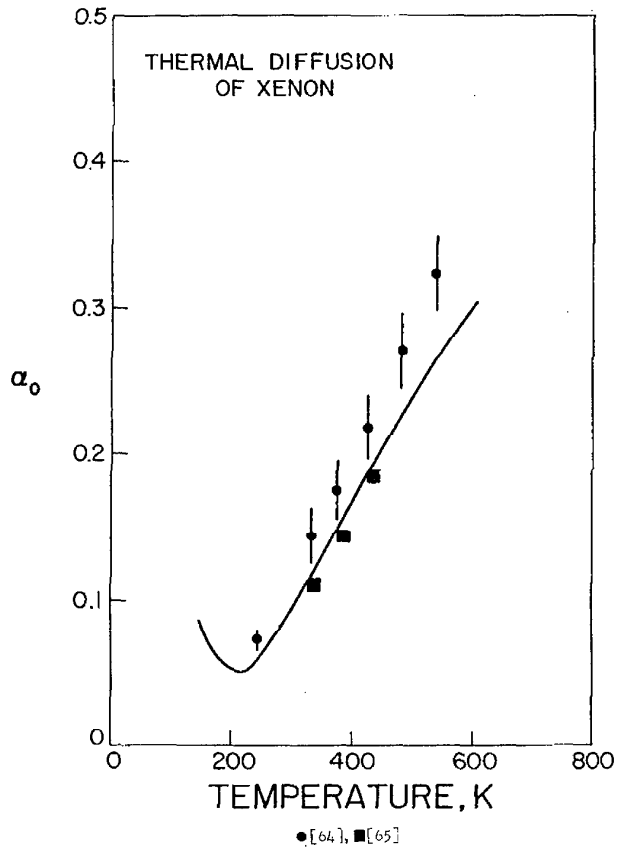


FIGURE 12. The isotopic thermal diffusion factor for xenon calculated from equation (10), using parameter given in table 2, compared to experiment.

Diffusion coefficients were calculated for argon and krypton from equation (16) using the parameters listed in table 2. Comparisons between calculated values and data from references [58–61] are shown in figures 8 and 9. Isotopic thermal diffusion factors were obtained from equation (10) for argon, krypton, and xenon and compared to data from references [62–65] in figures 10–12.

To summarize, figures 1–3 and 8–12, in conjunction with the experimental considerations, reinforce the conclusion that the tabulated viscosity and thermal conductivity coefficients are consistent with other properties of the gases, are free from serious systematic errors, and that the accuracy estimate quoted above is reasonable. In fact, based on the consistent representation of the virial coefficients, the diffusion coefficients and the isotopic thermal diffusion factor at low temperatures, the previous estimate of ±2 percent accuracy for the tabulated viscosity and thermal conductivity coefficients may be too high. Accordingly, we lower the estimate to ± 1 percent for temperatures between 80 and 100 K.

Unfortunately, the figures 1–3 and 8–12, do not properly resolve the discrepancy between the two sets of viscosity data, for all gases, above 1000 K. An accuracy assignment of ±1¾ percent, based on the difference between these data, is therefore given to our tabulated values for temperatures between 1000 and 2000 K.

4.2. The Potential Function and Extrapolation of the Tables

Although the m–6–8 is a very practical model to insert into statistical mechanical equations, it is not exact. We have discussed the various model potentials—particularly those for argon—that have been proposed [54, 55] and indicated how they can represent data on the one hand, and how they are compatible with known information on the nature of intermolecular interactions on the other hand. It seems that for "normal" temperatures—a reduced temperature range of $0.5 \leq T^* \leq 20$, say—the m–6–8 potential is completely adequate when required to represent macroscopic properties. Outside this range, however, intermolecular interactions depend strongly on the nature of the potential at small intermolecular separations (high temperatures) or at very large separations (low temperatures), and we have previously discussed that the form of the m–6–8 is insufficiently flexible to represent intermolecular interactions at these extremes. For example, it is shown in reference [55] that the potential is too hard at small r, and that numerical values of the dispersion coefficients (the coefficients of the $1/r^6$ and $1/r^8$ terms of equation (8)) do not agree with independent quantum mechanical estimates.

However, it is not yet clear how a "normal" temperature range can be properly defined, so one can only estimate at what temperatures the m–6–8 will fail to reproduce data. The problem is compounded because the available data for gases tend to become progressively more imprecise at very high or at very low temperatures. Our estimate is that the procedure presented here could be used to calculate transport properties for temperatures up to about 4000 K. An estimate for a lower limit would be about the triple point temperature. In any case, these limits are somewhat academic because ionization would occur at high temperatures, and the gas can only exist at an extremely low pressure at very low temperatures.

5. Conclusion

We have generated tables for the dilute gas viscosity and thermal conductivity coefficients for argon, krypton, and xenon using the m–6–8 potential with selected experimental data. On the basis of an analysis of the input data and from the results obtained when the m–6–8 potential, with parameters chosen to correlate the viscosity coefficients, was inserted into statistical mechanical equations for other properties, we place an estimate of uncertainty of one percent in the tabulated values for temperatures up to 1000 K. The uncertainty estimate is set at one and three quarters percent for temperatures between 1000 and 2000 K. A feature of this viscosity and thermal conductivity correlation is that these coefficients are consistent with other macroscopic properties of the dilute and moderately dense gas.

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TABLE 1. Selected references for viscosity and thermal conductivity data

Gas	Viscosity references	Thermal conductivity references
Ar	12–15, 22–27	20, 33–43, 48
Kr	12, 14–16	20, 40, 44–48
Xe	14, 15, 17, 28, 29	40, 44–49

TABLE. 2. Values of the parameters of the m–6–8 potential function that fit both transport and equilibrium properties

Gas	m	γ	σ Å, (1Å $\equiv 10^{-10}$ m)	ϵ/k K
Ar	11	3	3.297	152.8
Kr	11	3	3.513	215.8
Xe	11	3	3.843	294.6

TABLE 3. Viscosity and thermal conductivity coefficients of argon

TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$	TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$
80	0.0663	0.0517	330	0.2477	0.1935
85	0.0701	0.0547	335	0.2508	0.1960
90	0.0740	0.0578	340	0.2538	0.1983
95	0.0779	0.0608	345	0.2569	0.2007
100	0.0818	0.0638	350	0.2599	0.2031
105	0.0857	0.0669	355	0.2629	0.2054
110	0.0897	0.0700	360	0.2659	0.2078
115	0.0937	0.0732	365	0.2688	0.2101
120	0.0977	0.0763	370	0.2717	0.2124
125	0.1016	0.0793	375	0.2747	0.2147
130	0.1055	0.0824	380	0.2776	0.2170
135	0.1095	0.0855	385	0.2805	0.2193
140	0.1135	0.0886	390	0.2834	0.2215
145	0.1174	0.0917	395	0.2862	0.2238
150	0.1214	0.0947	400	0.2890	0.2260
155	0.1253	0.0978	405	0.2919	0.2282
160	0.1292	0.1008	410	0.2947	0.2304
165	0.1331	0.1038	415	0.2975	0.2326
170	0.1369	0.1069	420	0.3003	0.2348
175	0.1408	0.1099	425	0.3030	0.2369
180	0.1446	0.1129	430	0.3057	0.2391
185	0.1484	0.1158	435	0.3085	0.2412
190	0.1522	0.1188	440	0.3112	0.2434
195	0.1559	0.1217	445	0.3139	0.2455
200	0.1596	0.1246	450	0.3166	0.2476
205	0.1633	0.1275	455	0.3192	0.2497
210	0.1670	0.1304	460	0.3219	0.2517
215	0.1706	0.1332	465	0.3245	0.2538
220	0.1742	0.1360	470	0.3271	0.2559
225	0.1778	0.1388	475	0.3298	0.2579
230	0.1814	0.1416	480	0.3324	0.2600
235	0.1849	0.1444	485	0.3349	0.2620
240	0.1885	0.1472	490	0.3375	0.2640
245	0.1920	0.1499	495	0.3400	0.2660
250	0.1955	0.1526	500	0.3426	0.2680
255	0.1989	0.1553	510	0.3477	0.2720
260	0.2024	0.1580	520	0.3527	0.2760
265	0.2058	0.1607	530	0.3577	0.2799
270	0.2091	0.1633	540	0.3626	0.2837
275	0.2125	0.1659	550	0.3675	0.2876
280	0.2158	0.1685	560	0.3723	0.2914
285	0.2191	0.1711	570	0.3772	0.2952
290	0.2223	0.1737	580	0.3819	0.2989
295	0.2256	0.1762	590	0.3866	0.3026
300	0.2288	0.1787	600	0.3913	0.3063
305	0.2320	0.1813	610	0.3960	0.3099
310	0.2352	0.1837	620	0.4005	0.3135
315	0.2383	0.1862	630	0.4052	0.3171
320	0.2415	0.1887	640	0.4097	0.3207
325	0.2446	0.1911	650	0.4142	0.3243

TABLE 3. Viscosity and thermal conductivity coefficients of argon—Continued

TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$	TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$
660	0.4187	0.3278	1160	0.6140	0.4811
670	0.4232	0.3313	1170	0.6176	0.4839
680	0.4276	0.3348	1180	0.6210	0.4866
690	0.4320	0.3382	1190	0.6245	0.4893
700	0.4364	0.3417	1200	0.6280	0.4921
710	0.4407	0.3451	1210	0.6314	0.4948
720	0.4450	0.3484	1220	0.6348	0.4975
730	0.4493	0.3518	1230	0.6382	0.5001
740	0.4535	0.3551	1240	0.6416	0.5028
750	0.4578	0.3585	1250	0.6451	0.5055
760	0.4620	0.3618	1260	0.6484	0.5081
770	0.4661	0.3650	1270	0.6518	0.5108
780	0.4703	0.3683	1280	0.6552	0.5134
790	0.4744	0.3715	1290	0.6585	0.5161
800	0.4785	0.3748	1300	0.6619	0.5187
810	0.4826	0.3780	1310	0.6652	0.5213
820	0.4867	0.3812	1320	0.6685	0.5239
830	0.4907	0.3843	1330	0.6719	0.5265
840	0.4948	0.3875	1340	0.6752	0.5291
850	0.4987	0.3906	1350	0.6784	0.5317
860	0.5027	0.3938	1360	0.6817	0.5342
870	0.5067	0.3969	1370	0.6850	0.5368
880	0.5106	0.3999	1380	0.6883	0.5394
890	0.5145	0.4030	1390	0.6915	0.5419
900	0.5184	0.4061	1400	0.6947	0.5444
910	0.5223	0.4091	1410	0.6980	0.5470
920	0.5262	0.4122	1420	0.7012	0.5495
930	0.5300	0.4151	1430	0.7045	0.5521
940	0.5338	0.4182	1440	0.7077	0.5546
950	0.5376	0.4212	1450	0.7109	0.5571
960	0.5414	0.4241	1460	0.7140	0.5596
970	0.5452	0.4271	1470	0.7172	0.5621
980	0.5490	0.4301	1480	0.7204	0.5646
990	0.5527	0.4330	1490	0.7236	0.5671
1000	0.5564	0.4359	1500	0.7267	0.5696
1010	0.5601	0.4388	1510	0.7299	0.5720
1020	0.5638	0.4417	1520	0.7330	0.5745
1030	0.5675	0.4446	1530	0.7362	0.5769
1040	0.5712	0.4475	1540	0.7393	0.5794
1050	0.5748	0.4504	1550	0.7423	0.5818
1060	0.5785	0.4532	1560	0.7454	0.5842
1070	0.5821	0.4561	1570	0.7486	0.5867
1080	0.5857	0.4589	1580	0.7517	0.5891
1090	0.5892	0.4617	1590	0.7548	0.5916
1100	0.5929	0.4645	1600	0.7579	0.5940
1110	0.5964	0.4673	1610	0.7610	0.5964
1120	0.6000	0.4701	1620	0.7640	0.5988
1130	0.6035	0.4729	1630	0.7671	0.6012
1140	0.6071	0.4757	1640	0.7701	0.6036
1150	0.6106	0.4784	1650	0.7732	0.6060

TABLE 3. Viscosity and thermal conductivity coefficients of argon—Continued

TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$	TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$
1660	0.7762	0.6084	1910	0.8500	0.6662
1670	0.7793	0.6107	1920	0.8529	0.6685
1680	0.7823	0.6131	1930	0.8558	0.6707
1690	0.7853	0.6155	1940	0.8586	0.6730
1700	0.7883	0.6178	1950	0.8615	0.6752
1710	0.7912	0.6201	1960	0.8644	0.6775
1720	0.7943	0.6225	1970	0.8672	0.6797
1730	0.7973	0.6249	1980	0.8700	0.6819
1740	0.8003	0.6272	1990	0.8729	0.6842
1750	0.8032	0.6296	2000	0.8757	0.6864
1760	0.8062	0.6319			
1770	0.8092	0.6342			
1780	0.8121	0.6365			
1790	0.8151	0.6388			
1800	0.8180	0.6412			
1810	0.8210	0.6435			
1820	0.8239	0.6458			
1830	0.8268	0.6481			
1840	0.8297	0.6503			
1850	0.8326	0.6526			
1860	0.8355	0.6549			
1870	0.8384	0.6571			
1880	0.8414	0.6595			
1890	0.8443	0.6617			
1900	0.8472	0.6640			

TABLE 4. Viscosity and thermal conductivity coefficients of krypton

TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$	TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$
80	0.0740	0.0276	330	0.2789	0.1038
85	0.0780	0.0290	335	0.2827	0.1052
90	0.0819	0.0305	340	0.2865	0.1067
95	0.0859	0.0320	345	0.2903	0.1081
100	0.0899	0.0335	350	0.2940	0.1095
105	0.0940	0.0350	355	0.2978	0.1108
110	0.0980	0.0365	360	0.3015	0.1122
115	0.1021	0.0380	365	0.3052	0.1136
120	0.1063	0.0395	370	0.3088	0.1150
125	0.1105	0.0411	375	0.3125	0.1163
130	0.1146	0.0427	380	0.3161	0.1177
135	0.1188	0.0442	385	0.3197	0.1190
140	0.1230	0.0457	390	0.3233	0.1204
145	0.1271	0.0473	395	0.3268	0.1217
150	0.1314	0.0489	400	0.3304	0.1230
155	0.1357	0.0505	405	0.3339	0.1243
160	0.1401	0.0521	410	0.3374	0.1256
165	0.1443	0.0537	415	0.3409	0.1269
170	0.1486	0.0553	420	0.3443	0.1282
175	0.1528	0.0568	425	0.3478	0.1295
180	0.1570	0.0584	430	0.3512	0.1308
185	0.1612	0.0600	435	0.3546	0.1321
190	0.1654	0.0616	440	0.3580	0.1333
195	0.1697	0.0631	445	0.3614	0.1346
200	0.1740	0.0647	450	0.3648	0.1359
205	0.1782	0.0663	455	0.3681	0.1371
210	0.1825	0.0679	460	0.3715	0.1384
215	0.1867	0.0695	465	0.3748	0.1396
220	0.1909	0.0710	470	0.3781	0.1408
225	0.1950	0.0726	475	0.3814	0.1421
230	0.1992	0.0741	480	0.3847	0.1433
235	0.2034	0.0757	485	0.3880	0.1445
240	0.2075	0.0772	490	0.3912	0.1457
245	0.2116	0.0787	495	0.3944	0.1469
250	0.2158	0.0803	500	0.3977	0.1481
255	0.2199	0.0818	510	0.4041	0.1505
260	0.2239	0.0833	520	0.4104	0.1529
265	0.2280	0.0848	530	0.4167	0.1553
270	0.2320	0.0863	540	0.4229	0.1576
275	0.2361	0.0878	550	0.4291	0.1599
280	0.2401	0.0893	560	0.4353	0.1622
285	0.2440	0.0908	570	0.4413	0.1645
290	0.2480	0.0923	580	0.4474	0.1667
295	0.2519	0.0938	590	0.4533	0.1690
300	0.2559	0.0952	600	0.4593	0.1712
305	0.2597	0.0967	610	0.4651	0.1734
310	0.2636	0.0981	620	0.4710	0.1756
315	0.2674	0.0995	630	0.4768	0.1777
320	0.2713	0.1010	640	0.4825	0.1799
325	0.2751	0.1024	650	0.4882	0.1820

TABLE 4. Viscosity and thermal conductivity coefficients of krypton—Continued

TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$	TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$
660	0.4939	0.1841	1160	0.7387	0.2758
670	0.4995	0.1862	1170	0.7430	0.2774
680	0.5050	0.1883	1180	0.7473	0.2790
690	0.5106	0.1904	1190	0.7516	0.2806
700	0.5161	0.1925	1200	0.7559	0.2822
710	0.5215	0.1945	1210	0.7602	0.2839
720	0.5270	0.1965	1220	0.7645	0.2854
730	0.5324	0.1986	1230	0.7687	0.2870
740	0.5377	0.2005	1240	0.7729	0.2886
750	0.5431	0.2026	1250	0.7771	0.2902
760	0.5484	0.2045	1260	0.7813	0.2918
770	0.5536	0.2065	1270	0.7855	0.2933
780	0.5588	0.2085	1280	0.7897	0.2949
790	0.5640	0.2104	1290	0.7939	0.2964
800	0.5692	0.2123	1300	0.7980	0.2980
810	0.5743	0.2143	1310	0.8020	0.2995
820	0.5795	0.2162	1320	0.8062	0.3011
830	0.5845	0.2181	1330	0.8103	0.3026
840	0.5896	0.2200	1340	0.8144	0.3041
850	0.5946	0.2219	1350	0.8185	0.3057
860	0.5996	0.2237	1360	0.8226	0.3072
870	0.6045	0.2255	1370	0.8266	0.3087
880	0.6095	0.2274	1380	0.8306	0.3102
890	0.6144	0.2293	1390	0.8347	0.3117
900	0.6193	0.2311	1400	0.8387	0.3132
910	0.6241	0.2329	1410	0.8427	0.3147
920	0.6290	0.2347	1420	0.8466	0.3162
930	0.6338	0.2365	1430	0.8507	0.3177
940	0.6386	0.2383	1440	0.8546	0.3192
950	0.6434	0.2401	1450	0.8586	0.3207
960	0.6481	0.2419	1460	0.8625	0.3221
970	0.6529	0.2437	1470	0.8664	0.3236
980	0.6575	0.2454	1480	0.8704	0.3251
990	0.6622	0.2472	1490	0.8743	0.3265
1000	0.6669	0.2489	1500	0.8782	0.3280
1010	0.6715	0.2506	1510	0.8821	0.3294
1020	0.6761	0.2524	1520	0.8859	0.3309
1030	0.6807	0.2541	1530	0.8897	0.3323
1040	0.6853	0.2558	1540	0.8937	0.3338
1050	0.6898	0.2575	1550	0.8975	0.3352
1060	0.6944	0.2592	1560	0.9013	0.3366
1070	0.6989	0.2609	1570	0.9051	0.3381
1080	0.7034	0.2626	1580	0.9090	0.3395
1090	0.7078	0.2642	1590	0.9128	0.3409
1100	0.7123	0.2659	1600	0.9166	0.3423
1110	0.7167	0.2676	1610	0.9203	0.3438
1120	0.7212	0.2692	1620	0.9241	0.3452
1130	0.7256	0.2709	1630	0.9278	0.3466
1140	0.7299	0.2725	1640	0.9316	0.3480
1150	0.7343	0.2742	1650	0.9353	0.3494

TABLE 4. Viscosity and thermal conductivity coefficients of krypton—Continued

TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$	TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$
1660	0.9391	0.3508	1910	1.0298	0.3847
1670	0.9428	0.3522	1920	1.0333	0.3860
1680	0.9466	0.3536	1930	1.0368	0.3873
1690	0.9503	0.3550	1940	1.0403	0.3886
1700	0.9540	0.3563	1950	1.0438	0.3899
			1960	1.0473	0.3912
1710	0.9577	0.3577	1970	1.0508	0.3925
1720	0.9614	0.3591	1980	1.0542	0.3938
1730	0.9650	0.3605	1990	1.0578	0.3952
1740	0.9687	0.3618	2000	1.0612	0.3965
1750	0.9723	0.3632			
1760	0.9759	0.3646			
1770	0.9796	0.3659			
1780	0.9833	0.3673			
1790	0.9869	0.3687			
1800	0.9905	0.3700			
1810	0.9941	0.3714			
1820	0.9977	0.3727			
1830	1.0013	0.3741			
1840	1.0049	0.3754			
1850	1.0084	0.3767			
1860	1.0120	0.3780			
1870	1.0155	0.3794			
1880	1.0192	0.3807			
1890	1.0227	0.3821			
1900	1.0262	0.3834			

TABLE 5. Viscosity and thermal conductivity coefficients of xenon

TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$	TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$
			330	0.2556	0.0607
			335	0.2593	0.0616
			340	0.2630	0.0625
			345	0.2667	0.0633
			350	0.2704	0.0642
105	0.0876	0.0208	355	0.2740	0.0651
110	0.0911	0.0217	360	0.2777	0.0659
115	0.0946	0.0225	365	0.2813	0.0668
120	0.0982	0.0233	370	0.2849	0.0677
125	0.1017	0.0242	375	0.2885	0.0685
130	0.1053	0.0250	380	0.2921	0.0694
135	0.1089	0.0259	385	0.2956	0.0702
140	0.1125	0.0267	390	0.2992	0.0711
145	0.1162	0.0276	395	0.3028	0.0719
150	0.1198	0.0285	400	0.3063	0.0728
155	0.1235	0.0293	405	0.3098	0.0736
160	0.1271	0.0302	410	0.3133	0.0744
165	0.1309	0.0311	415	0.3168	0.0752
170	0.1347	0.0320	420	0.3203	0.0761
175	0.1384	0.0329	425	0.3237	0.0769
180	0.1421	0.0338	430	0.3272	0.0777
185	0.1458	0.0346	435	0.3306	0.0785
190	0.1496	0.0355	440	0.3341	0.0794
195	0.1533	0.0364	445	0.3374	0.0802
200	0.1571	0.0373	450	0.3409	0.0810
205	0.1609	0.0382	455	0.3443	0.0818
210	0.1648	0.0391	460	0.3477	0.0826
215	0.1687	0.0401	465	0.3511	0.0834
220	0.1726	0.0410	470	0.3545	0.0842
225	0.1764	0.0419	475	0.3578	0.0850
230	0.1802	0.0428	480	0.3612	0.0858
235	0.1840	0.0437	485	0.3645	0.0866
240	0.1877	0.0446	490	0.3679	0.0874
245	0.1915	0.0455	495	0.3712	0.0882
250	0.1953	0.0464	500	0.3745	0.0890
255	0.1991	0.0473	510	0.3810	0.0905
260	0.2029	0.0482	520	0.3875	0.0921
265	0.2067	0.0491	530	0.3940	0.0936
270	0.2105	0.0500	540	0.4003	0.0951
275	0.2143	0.0509	550	0.4067	0.0966
280	0.2181	0.0518	560	0.4129	0.0981
285	0.2220	0.0527	570	0.4192	0.0996
290	0.2257	0.0536	580	0.4254	0.1011
295	0.2295	0.0545	590	0.4315	0.1026
300	0.2333	0.0554	600	0.4376	0.1040
305	0.2370	0.0563	610	0.4437	0.1055
310	0.2407	0.0572	620	0.4497	0.1069
315	0.2445	0.0581	630	0.4557	0.1083
320	0.2482	0.0589	640	0.4616	0.1097
325	0.2519	0.0598	650	0.4675	0.1112

TABLE 5. Viscosity and thermal conductivity coefficients of xenon—Continued

TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$	TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$
660	0.4734	0.1126	1160	0.7273	0.1732
670	0.4792	0.1139	1170	0.7317	0.1743
680	0.4850	0.1153	1180	0.7362	0.1753
690	0.4908	0.1167	1190	0.7405	0.1763
700	0.4965	0.1181	1200	0.7451	0.1774
710	0.5021	0.1194	1210	0.7494	0.1785
720	0.5078	0.1208	1220	0.7538	0.1795
730	0.5134	0.1221	1230	0.7582	0.1806
740	0.5190	0.1234	1240	0.7626	0.1816
750	0.5245	0.1248	1250	0.7669	0.1827
760	0.5301	0.1261	1260	0.7712	0.1837
770	0.5355	0.1274	1270	0.7755	0.1847
780	0.5409	0.1287	1280	0.7799	0.1858
790	0.5463	0.1300	1290	0.7841	0.1868
800	0.5517	0.1312	1300	0.7884	0.1878
810	0.5571	0.1325	1310	0.7927	0.1888
820	0.5624	0.1338	1320	0.7969	0.1898
830	0.5676	0.1350	1330	0.8011	0.1908
840	0.5729	0.1363	1340	0.8052	0.1918
850	0.5781	0.1375	1350	0.8095	0.1928
860	0.5832	0.1388	1360	0.8137	0.1938
870	0.5884	0.1400	1370	0.8178	0.1948
880	0.5935	0.1412	1380	0.8220	0.1958
890	0.5986	0.1424	1390	0.8261	0.1968
900	0.6037	0.1437	1400	0.8302	0.1978
910	0.6087	0.1449	1410	0.8344	0.1988
920	0.6137	0.1461	1420	0.8385	0.1998
930	0.6187	0.1473	1430	0.8425	0.2007
940	0.6237	0.1484	1440	0.8466	0.2017
950	0.6286	0.1496	1450	0.8507	0.2027
960	0.6335	0.1508	1460	0.8547	0.2036
970	0.6384	0.1520	1470	0.8588	0.2046
980	0.6433	0.1531	1480	0.8627	0.2056
990	0.6481	0.1543	1490	0.8667	0.2065
1000	0.6530	0.1554	1500	0.8708	0.2075
1010	0.6577	0.1566	1510	0.8747	0.2084
1020	0.6625	0.1577	1520	0.8787	0.2094
1030	0.6673	0.1589	1530	0.8827	0.2103
1040	0.6720	0.1600	1540	0.8866	0.2113
1050	0.6768	0.1611	1550	0.8905	0.2122
1060	0.6814	0.1622	1560	0.8945	0.2131
1070	0.6861	0.1633	1570	0.8984	0.2141
1080	0.6908	0.1645	1580	0.9023	0.2150
1090	0.6954	0.1656	1590	0.9062	0.2159
1100	0.7000	0.1667	1600	0.9101	0.2169
1110	0.7046	0.1678	1610	0.9140	0.2178
1120	0.7092	0.1689	1620	0.9178	0.2187
1130	0.7137	0.1699	1630	0.9216	0.2196
1140	0.7182	0.1710	1640	0.9254	0.2205
1150	0.7228	0.1721	1650	0.9293	0.2215

TABLE 5. Viscosity and thermal conducitivity coefficients of xenon—Continued

TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$	TEMPERATURE K	VISCOSITY G/CM-S $10^3\eta$	THERMAL CONDUCTIVITY W/CM-K $10^3\lambda$
1660	0.9331	0.2224	1910	1.0256	0.2445
1670	0.9369	0.2233	1920	1.0292	0.2453
1680	0.9407	0.2242	1930	1.0327	0.2462
1690	0.9445	0.2251	1940	1.0363	0.2470
1700	0.9483	0.2260	1950	1.0398	0.2478
			1960	1.0435	0.2487
1710	0.9521	0.2269	1970	1.0470	0.2496
1720	0.9558	0.2278	1980	1.0506	0.2504
1730	0.9596	0.2287	1990	1.0541	0.2513
1740	0.9633	0.2296	2000	1.0576	0.2521
1750	0.9671	0.2305			
1760	0.9708	0.2314			
1770	0.9745	0.2323			
1780	0.9782	0.2331			
1790	0.9818	0.2340			
1800	0.9855	0.2349			
1810	0.9893	0.2358			
1820	0.9929	0.2367			
1830	0.9966	0.2375			
1840	1.0003	0.2384			
1850	1.0039	0.2393			
1860	1.0075	0.2401			
1870	1.0112	0.2410			
1880	1.0148	0.2419			
1890	1.0184	0.2427			
1900	1.0220	0.2436			

Appendix A

Collision integrals, and combinations of the integrals, required for the transport property calculations are reproduced from reference [56]. We also include tables of the reduced second virial coefficients.

Collision integrals for the 11-6-8 ($\gamma=3.0$) potential

T^*	$\Omega^{(1,1)*}$	$\Omega^{(1,2)*}$	$\Omega^{(2,2)*}$	$\Omega^{(1,3)*}$	$\Omega^{(2,3)*}$	$\Omega^{(3,3)*}$
0.6000	1.77495683	1.50044068	1.97292436	1.31799182	1.75119807	1.62664569
0.6500	1.71029244	1.44430297	1.90393332	1.27150018	1.68427961	1.56699361
0.7000	1.65268780	1.39511086	1.83999062	1.23134857	1.62310690	1.51434932
0.7500	1.59908326	1.34980755	1.77844390	1.19570368	1.56853486	1.46629105
0.8000	1.55313888	1.31078609	1.72505031	1.16477532	1.52060206	1.42331600
0.8500	1.50943774	1.27685162	1.67759146	1.13794402	1.47708942	1.38516896
0.9000	1.46922464	1.24690235	1.63261115	1.11429982	1.43791883	1.35111649
0.9500	1.43430228	1.21885599	1.59074373	1.09308629	1.40277761	1.32011258
1.0000	1.40190117	1.19315885	1.55245548	1.07387989	1.37099892	1.29166006
1.1000	1.34357947	1.14923890	1.48592018	1.04096448	1.31621990	1.24211144
1.2000	1.29400805	1.11350836	1.42835730	1.01376097	1.27020089	1.20067018
1.3000	1.25350469	1.08291541	1.37936665	0.99076132	1.23131087	1.16550068
1.4000	1.21753570	1.05644518	1.33706527	0.97101082	1.19832065	1.13518176
1.5000	1.18421312	1.03359443	1.30037160	0.95379473	1.16989256	1.10879871
1.6000	1.15504628	1.01369579	1.26748280	0.93866542	1.14515079	1.08571844
1.7000	1.12997253	0.99605801	1.23842116	0.92523500	1.12343252	1.06539195
1.8000	1.10801605	0.98032225	1.21281020	0.91321359	1.10414466	1.04735142
1.9000	1.08807262	0.96617115	1.19000803	0.90233838	1.08693482	1.03119717
2.0000	1.06958556	0.95330369	1.16943369	0.89242579	1.07150251	1.01661888
2.2000	1.03769859	0.93098908	1.13394880	0.87496953	1.04494356	0.99132506
2.4000	1.01099595	0.91222000	1.10430496	0.86001408	1.02282001	0.97012749
2.6000	0.98812353	0.89605171	1.07911862	0.84700946	1.00399848	0.95198017
2.8000	0.96833164	0.88188385	1.05760250	0.83545818	0.98777679	0.93635700
3.0000	0.95078230	0.86935931	1.03897395	0.82511265	0.97355794	0.92267975
3.2000	0.93533311	0.85817805	1.02262673	0.81576952	0.96097407	0.91051120
3.4000	0.92165145	0.84808145	1.00809869	0.80725371	0.94971433	0.89959636
3.6000	0.90944407	0.83888754	0.99507016	0.79943579	0.93955025	0.88972610
3.8000	0.89830455	0.83048268	0.98332893	0.79220960	0.93029732	0.88074277
4.0000	0.88805170	0.82273302	0.97266670	0.78549248	0.92181381	0.87251447
4.5000	0.86583179	0.80570453	0.94972898	0.77053955	0.90331730	0.85454060
5.0000	0.84748180	0.79123150	0.93087726	0.75764824	0.88775363	0.83942074
5.5000	0.83178498	0.77866684	0.91494074	0.74632705	0.87436348	0.82639695
6.0000	0.81824763	0.76758447	0.90118200	0.73623864	0.86261104	0.81497356
6.5000	0.80636877	0.75767422	0.88909357	0.72714416	0.85214217	0.80481054
7.0000	0.79575232	0.74872313	0.87833881	0.71886917	0.84270646	0.79565537
7.5000	0.78617885	0.74056466	0.86866131	0.71128089	0.83411929	0.78732605
8.0000	0.77746627	0.73306709	0.85986201	0.70427535	0.82623927	0.77968899
8.5000	0.76948072	0.72613592	0.85180140	0.69777133	0.81895853	0.77263782
9.0000	0.76211483	0.71969252	0.84436560	0.69170305	0.81219147	0.76608977
9.5000	0.75528526	0.71367522	0.83746685	0.68601729	0.80587034	0.75997739
10.0000	0.74893100	0.70803109	0.83103386	0.68066998	0.79993999	0.75424598
12.0000	0.72717121	0.68842664	0.80892213	0.66200350	0.77931652	0.73434495
14.0000	0.70961693	0.67234483	0.79097716	0.64660102	0.76234894	0.71800629
16.0000	0.69491929	0.65873431	0.77587443	0.63351590	0.74794007	0.70415536
18.0000	0.68228800	0.64695238	0.76283719	0.62216028	0.73542548	0.69214297
20.0000	0.67122838	0.63657807	0.75137094	0.61214403	0.72437144	0.68154551
26.0000	0.64454920	0.61136970	0.72350146	0.58775833	0.69736849	0.65570675
30.0000	0.63045621	0.59797285	0.70865817	0.57478102	0.68293315	0.64192048

Collision integral combinations for the 11–6–8 ($\gamma=3.0$) potential

T^*	f_η	f_λ	f_D	α_0	T^*	f_η	f_λ	f_D	α_c
0.600	1.0002	1.0002	1.0001	0.0614	3.000	1.0038	1.0059	1.0041	0.4102
0.650	1.0001	1.0001	1.0001	0.0566	3.200	1.0041	1.0064	1.0044	0.4267
0.700	1.0000	1.0001	1.0001	0.0547					
0.750	1.0000	1.0001	1.0001	0.0543	3.400	1.0044	1.0069	1.0047	0.4406
0.800	1.0000	1.0001	1.0001	0.0534	3.600	1.0047	1.0073	1.0050	0.4524
					3.800	1.0049	1.0077	1.0052	0.4633
0.850	1.0000	1.0000	1.0001	0.0631	4.000	1.0052	1.0081	1.0054	0.4735
0.900	1.0000	1.0001	1.0001	0.0770	4.500	1.0057	1.0088	1.0059	0.4950
0.950	1.0000	1.0001	1.0002	0.0825					
1.000	1.0001	1.0001	1.0002	0.0889	5.000	1.0061	1.0094	1.0063	0.5110
1.100	1.0001	1.0002	1.0003	0.1100	5.500	1.0064	1.0099	1.0066	0.5239
					6.000	1.0066	1.0103	1.0069	0.5339
1.200	1.0002	1.0003	1.0005	0.1358	6.500	1.0068	1.0106	1.0071	0.5417
1.300	1.0003	1.0005	1.0006	0.1528	7.000	1.0070	1.0109	1.0072	0.5482
1.400	1.0004	1.0007	1.0007	0.1717					
1.500	1.0006	1.0009	1.0010	0.1972	7.500	1.0071	1.0111	1.0074	0.5536
1.600	1.0008	1.0012	1.0012	0.2215	8.000	1.0072	1.0112	1.0075	0.5581
					8.500	1.0073	1.0114	1.0076	0.5619
1.700	1.0010	1.0016	1.0015	0.2411	9.000	1.0074	1.0115	1.0077	0.5652
1.800	1.0012	1.0019	1.0017	0.2577	9.500	1.0075	1.0116	1.0078	0.5679
1.900	1.0014	1.0022	1.0019	0.2740					
2.000	1.0017	1.0026	1.0021	0.2909	10.000	1.0075	1.0117	1.0078	0.5702
2.200	1.0021	1.0033	1.0026	0.3210	12.000	1.0077	1.0119	1.0080	0.5762
					14.000	1.0077	1.0120	1.0081	0.5793
2.400	1.0026	1.0040	1.0030	0.3475	16.000	1.0078	1.0121	1.0082	0.5809
2.600	1.0030	1.0047	1.0034	0.3710	18.000	1.0078	1.0121	1.0082	0.5817
2.800	1.0034	1.0053	1.0038	0.3913	20.000	1.0078	1.0121	1.0082	0.5820

Second virial coefficients for the 11–6–8 ($\gamma=3.0$) potential

T^*	B^*	T^*	B^*
0.60000	−4.87068	3.20000	0.14054
0.65000	−4.17866	3.40000	0.18044
0.70000	−3.63207	3.60000	0.21519
0.75000	−3.19016	3.80000	0.24568
0.80000	−2.82595	4.00000	0.27260
0.85000	−2.52090	4.50000	0.32768
0.90000	−2.26188	5.00000	0.36984
0.95000	−2.03934	5.50000	0.40287
1.00000	−1.84619	6.00000	0.42925
1.10000	−1.52774	6.50000	0.45064
1.20000	−1.27637	7.00000	0.46820
1.30000	−1.07314	7.50000	0.48277
1.40000	−0.90561	8.00000	0.49495
1.50000	−0.76526	8.50000	0.50522
1.60000	−0.64607	9.00000	0.51392
1.70000	−0.54368	9.50000	0.52134
1.80000	−0.45482	10.00000	0.52768
1.90000	−0.37705	12.00000	0.54528
2.00000	−0.30844	14.00000	0.55495
2.20000	−0.19307	16.00000	0.56008
2.40000	−0.10001	18.00000	0.56244
2.60000	−0.02353	20.00000	0.56304
2.80000	0.04033	26.00000	0.55939
3.00000	0.09434	30.00000	0.55484