The Viscosity and Thermal Conductivity Coefficients for Dense Gaseous and Liquid Argon, Krypton, Xenon, Nitrogen, and Oxygen

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Data for the viscosity and thermal conductivity coefficients of argon, nitrogen, and oxygen have been critically evaluated. A functional form to represent the data has been proposed. The function is basically the same for both coefficients. The critical point enhancement in the thermal conductivity coefficient is included. Transport properties of krypton and xenon are calculated by means of the principle of corresponding states. Tables of values are presented in the range from about the triple point temperature to 500 K for pressures up to 100 MPa. 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 previously determined. The uncertainties of the tabulated coefficients are discussed in the text. The correlation further serves to clarify the state of the art concerning transport data and experiment and to emphasize gaps in data coverage.

Key words: Argon; correlation; critical data evaluation; critical point; dense gas and liquid; excess transport property functions; krypton; nitrogen; oxygen; tables; thermal conductivity coefficient; transport property; viscosity coefficient; xenon.

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* Supported by the Office of Standard Reference Data.

Nomenclature

T	temperature
P	pressure
R	gas constant
K_T	compressibility
ρ	mass density
η	viscosity coefficient
η_0	dilute gas viscosity
η_1	viscosity first density correction
$\Delta\eta$	excess viscosity
j_i $(i=1, 7)$	viscosity equation parameters
λ	thermal conductivity coefficient
λ_0	dilute gas thermal conductivity
λ_1	thermal conductivity first density correction
$\Delta\lambda$	excess thermal conductivity
$\Delta\lambda_c$	critical region excess thermal conductivity
k_i $(i=1, 4)$	thermal conductivity equation parameters
M	molecular weight
N	Avogadro's number
k	Boltzmann's constant
φ	intermolecular pair potential
$m, \gamma', \sigma, r_m, \epsilon$	potential parameters
γ, N_i $(i=1, 32)$	equation of state parameters
A, B, C	first density correction equation parameters
θ	viscosity equation variable
*	reduced variable superscript
c	critical point variable subscript
$x_0, \beta, E_1, E_2, \delta, \gamma''$	scaling parameters for the compressibility in the critical region
l	length parameter in the critical point equation
q, t, x, y	parameters in the equation for the thermal conductivity enhancement

1. Introduction

The transport properties of argon, krypton, xenon, nitrogen, and oxygen are discussed in this paper. Our objectives are to evaluate viscosity-coefficient (η) and thermal-conductivity-coefficient (λ) measurements, to establish equations to represent selected data, and to generate tables of recommended values. Tables of the coefficients are presented for temperatures (T) extending from about the triple point temperature to 500 K, and for pressures (P) up to 100 MPa.

It will be shown that the correlation procedure takes into account the enhancement in the thermal conductivity coefficient in the critical region. It should be noted that the recommended thermal conductivity and viscosity coefficients are consistent with an equation of state for each fluid and are also consistent with dilute gas values previously discussed [1, 2][1]. It will, further, be apparent that the empirical function proposed to correlate the data seems to be general; i.e., essentially one function applies to both transport properties for the given fluids and there are strong indications that the function can be used for other fluids.

2. Data Selection

In previous work with the rare gases [1] and nitrogen and oxygen [2], dilute-gas data were analyzed using statistical mechanics and kinetic theory. This approach had one particular advantage in that the effects of scatter and imprecision in the data were minimized. In fact, theoretically calculated thermal conductivity coefficients were presented in preference to empirical fits of the experimental measurements which were of dubious reliability. However, the correlation covered the dilute gas only and this approach cannot be followed for the dense gas and liquid; i.e., transport theory is inadequate for dense fluids[2]. Thus a correlation of dense-fluid-transport coefficients has to be based entirely on experimental data which obviously have to be selected with care, since the data often vary greatly in precision.

To systematically select data from the literature and assign accuracies to the data we have set up criteria and evaluated the experimental papers against them. These criteria are based on a discussion reported in reference [5] concerning the presentation and evaluation of thermal conductivity experiments and are given below.

2.1. Criteria

A paper can only be evaluated objectively from its contents. It is desirable, therefore, that the paper can satisfy as many of the following points as possible:

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[1] Numbers in brackets refer to the references on page 995.

[2] Progress has been made with semi-theoretical methods, such as the modified Enskog theory [3] and recent computer simulation studies appear to be relatively successful [4], but not to the point of providing a definitive correlation of the transport coefficients in the dense gas and liquid.

1. The paper must provide
   a) experimental details
   b) the working equation with correction factors
   c) uncorrelated results in tabular form.
2. If the experimental procedure is a relative method the paper should give complete details of the calibrations.
3. The paper should contain a discussion on the reproducibility and precision of the data so that the results can be checked for internal consistency.
4. The paper should contain a discussion on possible systematic errors leading to an accuracy assessment of the data. The paper needs to include, therefore:
   a) The full working equation from which the viscosity or thermal conductivity coefficient was calculated, and a discussion of the appropriate correction terms.
   b) A description of the measurement of the parameters that need to be entered into the working equation and estimates of their uncertainties. If independent sources were required to obtain some of these parameters, the sources should be clearly referenced.
   c) A complete description of the temperature, pressure and, if necessary, density measurements.[3]
   d) A description of the geometric constants of the sample cell and a discussion on their probable variation.
   e) Statements on the purity and composition of the sample fluid and a discussion on the verification that the purity and composition are maintained during the course of an experiment.

In addition to the above, reference [5] lists the following which should be covered in a paper on thermal conductivity:

f) A direct experimental assessment of radiative losses.
g) Experimental proof of the absence of convection.
h) A discussion of parasitic conduction and of the efforts made to estimate its magnitude and correct for it.
i) A discussion of the temperature-gradient measurement including specification of the size of the temperature difference and a discussion of the relation of the measured temperature difference and the gradient in the fluid.
j) A discussion of the method of measuring heat flow and its accuracy.
k) Experimental confirmation that the measured thermal conductivity is independent of the magnitude of the temperature gradient (Fourier's law).
l) Comments on the geometry of the temperature field.
m) Discussion of accommodation coefficients if appropriate.

2.2. Excess Functions

It has been demonstrated [6] that a convenient preliminary evaluation of transport data is obtained by examining the behavior of the excess functions defined by the relations:

For viscosity

$$\Delta\eta(\rho, T) = \eta(\rho, T) - \eta_0(T). \tag{1}$$

For thermal conductivity

$$\Delta\lambda(\rho, T) = \lambda(\rho, T) - \lambda_0(T). \tag{2}$$

$\eta_0(T)$ and $\lambda_0(T)$ are the dilute gas values for the viscosity and thermal conductivity, respectively, at a given temperature, T; while $\eta(\rho, T)$ and $\lambda(\rho, T)$ are the total values at a density, ρ, at the same temperature.

The general behavior of the transport coefficients for classical fluids in the excess function format is sketched in figure 1. Note that $\Delta\eta$ and $\Delta\lambda$ are smooth functions of density and are weakly dependent on temperature. The temperature dependence, although small, differs in sign between the two transport coefficients; above the critical density, the derivative $(\partial\Delta\eta/\partial T)_\rho$ is negative whereas $(\partial\Delta\lambda/\partial T)_\rho$ is positive. The critical region enhancement in the thermal conductivity has not been included in figure 1.

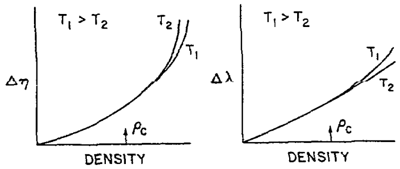

FIGURE 1. Schematic representation of the excess viscosity, $\Delta\eta$, and excess thermal conductivity, $\Delta\lambda$, plotted versus density. Note $(\partial\Delta\eta/\partial T)\rho$ is negative but $(\partial\Delta\lambda/\partial T)\rho$ is positive. See reference [6].

Further, to first order in density

$$\begin{aligned}\Delta\eta(\rho, T) &= \eta_1(T)\rho,\\ \Delta\lambda(\rho, T) &= \lambda_1(T)\rho,\end{aligned} \tag{3}$$

where $\eta_1(T)$ and $\lambda_1(T)$ are defined as first density corrections. A statistical procedure has been developed [7] to estimate values of these coefficients, and to determine systematically the internal consistency of transport coefficients of moderately dense gases. Reference [7] gives the details, but basically the procedure fits data to a power series[4] in density, e.g.,

$$\eta(\rho, \mathrm{T}) = \eta_0 + \eta_1\rho + \eta_2\rho^2 + \ldots \tag{4}$$

(and similarly for the thermal conductivity). The general behavior of $\eta_1(T)$ and $\lambda_1(T)$ is outlined in figure 2. Note

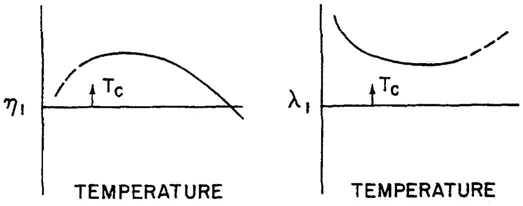

FIGURE 2. Schematic diagram of the first density corrections, η_1 and λ_1, plotted versus temperature. See reference [7].

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[3] Errors in these properties can affect the error in the final computation of the transport property, as for b), but the transport properties could also be reported for an incorrect point in the $P\rho T$ space. (This can be especially serious if the experiments concern the two-phase boundary or the critical region.)

[4] It is not relevant for the purposes of this paper to discuss whether a power series expansion, or an expansion containing logarithmic terms in density is correct.

that $\eta_1(T)$ goes through zero at high temperatures.

In summary: A subjective but significant test to apply to a set of transport data is to examine the measurements in the excess function format. One expects that the behavior noted in figure 1 would be observed. If appropriate the first density correction should be evaluated by the method of reference [7]. This evaluation also leads to estimates of the dilute gas coefficients, $\eta_0(T)$ and $\lambda_0(T)$, which can then be compared to kinetic calculations and to data obtained from independent experiments.

2.3. Selection Procedure

In order to select data for our correlation we assembled a bibliography of the experimental papers and examined each paper in terms of the criteria set forth in section 2.1. For a given paper that satisfied criterion 1—and it turned out that the most common reason for rejecting a data set was that the first criterion could not be met—the internal consistency and precision of the reported measurements were checked. A graphical examination of the data provided a good first estimate of the consistency and precision. A more quantitative estimate followed if the experiment was carried out in the dense gas region by applying the statistical procedure of reference [7].

Given an internally consistent data set, an accuracy assessment was made following the points listed in criterion 4 of section 2.1 as closely as possible. Our own estimates were compared to the author's and, if possible, discrepancies clarified.

When appropriate the data were plotted versus density in the excess function format, equation (1) or (2). Any deviations from the expected pattern sketched in figure 1 were noted and led to re-examination of the possible systematic errors in the data. Similarly, any discrepancies between data for a particular fluid, obtained from different authors who covered the same temperature and pressure ranges, led to a further check on the accuracy assessment of the data.

TABLE 1. Selected references for argon

Authors	Approximate experimental range	Estimated accuracy ±%	Apparatus[a]
	Viscosity		
Kestin, Paykoc Sengers [10]	298 K pressures to 10 MPa	0.4%	OD
Haynes [12]	85–298 K pressures to 34 MPa	2%	TOC
Kestin and Whitelaw [33]	295–537 K pressures to 14 MPa	1%	OD
Michels, Botzen Schuurman [34]	273–348 K pressures to 200 MPa	0.75%	CF
Gracki, Flynn Ross [35]	173–298 K pressures to 17 MPa	1%	CF
Boon, Legros Thomaes [36]	84–89 K saturated liquid	3%	CF
	Thermal conductivity		
Sengers [21, 37]	273–348 K pressures to 200 MPa	1½%	PP
Le Neindre [23]	298–977 K pressures to 126 MPa	4%	CC
Ziebland and Burton [38]	93–195 K pressures to 12 MPa	4%	CC

[a] TOC = torsional oscillating crystal.
OD = oscillating disc.
CF = capillary flow.
CC = concentric cylinder.
PP = parallel plate.

TABLE 2. Selected references for nitrogen

Authors	Approximate experimental range	Estimated accuracy ±%	Apparatus
	Viscosity		
Kestin, Paykoc Sengers [10]	298 K pressures to 10.5 MPa	0.4%	OD
Kestin and Whitelaw [33]	348–538 K pressures to 14 MPa	1%	OD
Gracki, Flynn Ross [35]	183–298 K pressures to 25 MPa	1%	CF
Boon, Legros Thomaes [36]	68–70 K saturated liquid	3%	CF
Gibson [39]	298–348 K pressures to 100 MPa	1%	CF
Hellemans, Zink Van Paemel [40]	96–120 K saturated liquid *only*	3%	OD
Kao and Kobayashi [41]	183–323 K pressures to 50 MPa	2%	CF
	Thermal conductivity		
Le Neindre [23]	298–800 K pressures to 100 MPa	4%	CC
Ziebland and Burton [38]	87–200 K pressures to 13 MPa	4%	CC
Uhlir [42]	76–184 K pressures to 7 MPa	5%	CC

TABLE 3. Selected references for oxygen

Authors	Approximate experimental range	Estimated accuracy ±%	Apparatus
	Viscosity		
Haynes [13]	75–300 K pressures to 34 MPa	2%	TOC
Boon, Legros Thomaes [36]	75–91 K staturated liquid	3%	CF
	Thermal conductivity		
Ziebland and Burton [43]	79–200 K pressures to 12 MPa	4%	CC
Ivanov, Tsederberg, Popov [94]	273–313 K pressures to 50 MPa used *only*	10%	CC

TABLE 4. Other experimental references concerning argon, krypton, xenon, nitrogen, and oxygen. Entries in the tables are the reference numbers.

Fluid	Viscosity	Thermal conductivity
Argon	46. 47, 51. 52, 55, 60. 61, 62, 68, 69, 70, 71, 72, 73, 74, 114, 116, 117, 118, 119, 120, 121, 122, 126	42, 44, 55, 56, 57, 58, 59, 66, 67
Krypton	36, 65, 68, 69, 114, 119, 123, 124	57, 64, 92
Xenon	36, 69, 93, 114, 119, 132,	57, 63, 92
Nitrogen	29, 45, 51, 52, 53, 54, 55, 61, 68, 70, 71, 72, 73, 75, 76, 77, 78, 79, 81, 83, 84, 115, 117, 118, 119, 122, 123, 124, 125, 127, 128, 129, 130, 131	44, 48, 49, 50, 66, 85, 87, 88, 89, 90, 91
Oxygen	29, 40, 45, 46, 47, 51, 52, 61, 74. 80. 82. 84. 119. 124. 125	91, 95, 96

2.4. Data Selected

Tables 1–3 summarize the references selected as data sources for the correlation. The experimental range, the apparatus, and our estimated accuracy are given for each reference. Other data considered, but not included in the correlation, are listed in table 4. Two remarks concerning data selection should be noted:

1. Transport properties of krypton and xenon are not included in tables 1–3 because they were estimated via the principle of corresponding states.[5]
2. In three cases experimental data were used because no better data for that particular pressure and temperature range exist; reference [40] was used for the saturated liquid viscosity of nitrogen; reference [94] provided a room temperature isotherm for the thermal conductivity of oxygen; and low temperature thermal

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[5] See footnote on page 11.

conductivity values for nitrogen were taken from reference [42]. These data were included to insure that the correlating equations were well behaved at the appropriate pressures and temperatures (but they are not necessarily as reliable as the other data in tables 1–3).

2.5. Experimental Methods

Experimental techniques will not be discussed in detail but it is apparent that, when data are evaluated by means of the criteria of section 2.1, certain apparatuses appear consistently to give results which can be considered superior.

Viscosity

The majority of the more reliable viscosity data in the literature was obtained from methods using either a capillary flow (CF) or an oscillating disc (OD) apparatus. Recent studies on the theoretical background and mechanics of the methods indicate that both are now well understood. For example, Kestin has re-examined the theory of the capillary flow technique [8] and refined and extended work with the oscillating disc [9, 10]. For representative discussions on recent experimental applications of these procedures refer to Gracki [11] and to Kestin [10] for the capillary flow and oscillating disc, respectively.

A third method appears to give good viscosity results and makes use of a torsional oscillating crystal[6] (TOC). The torsional oscillating crystal has the advantage of applicability over wide ranges of pressure and temperature with relative ease [12–16]. The theoretical basis of the method and mechanics of this apparatus have been studied by several authors [17–20]. Our conclusion is that it is an excellent and useful technique but that it is not as well developed as the apparatuses making use of a capillary or oscillating disc. A detailed discussion of the torsional oscillating crystal has been presented by Haynes in describing its application to viscosity measurements for argon [12].

Thermal Conductivity

Perhaps more so than for the viscosity coefficient, the reliability of experimental thermal conductivity coefficients depends strongly on the experimental procedure followed in a particular case, irrespective of the apparatus chosen. However it is apparent that two techniques—parallel plate (PP) or concentric cylinders (CC) apparatuses—are responsible for the more reliable results. Reference should be made to the thesis of Sengers [21] for a description of the former, and to Guildner [22] and Le Neindre [23] for a discussion on the latter.

It should be remarked that several papers have recently been published describing a non-stationary state (transient) method. For example, see the work of Mani and Venart [24], Davis et al. [25], and McLaughlin and Pittman [26]. 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 improved experimental techniques, especially the use of equipment allowing the accurate measurement of a small temperature rise within a fraction of a second after the heating current is applied.

The transient hot wire approach appears to have considerable potential. Unfortunately, results are not yet available for the fluids of interest here and the method cannot be applied to cover the important region close to the critical point without modifications. Moreover, further work has to be done to establish the reliability of the data from the method: the transient hot wire is a flexible and convenient apparatus but the results are not necessarily as accurate as equivalent data obtained from either a parallel plate or a concentric cylinder apparatus, all other factors being equal.

General references that should be consulted for details on experimental techniques include, for viscosity: Bruges and Whitelaw [27], Barr [28] and Golubev [29], and for thermal conductivity: Tye [30], Vargaftik [31], and Tsederberg [32].

3. Correlation

Equation of State

The equation of state is central to our analysis. Although the majority of transport results were reported in temperature-pressure coordinates, the internal consistency of a given set was often assessed by examining the data as functions of temperature and density. Data were also examined in the excess function form, equations (1) or (2), whenever possible. Further, we are of the opinion that a proper correlation of transport coefficients can be carried out *only* in terms of temperature and density.

The equations of state needed are based on the Strobridge modification [97] of the Benedict-Webb-Rubin equation developed by McCarty and co-workers [98, 99]. The specific functional form of the oxygen and nitrogen equations used here was reported by Jacobsen [100]. The argon equation is essentially that of Gosman, McCarty, and Hust [98] but transformed into the functional form of Jacobsen. In this manner, all three fluids have an equation of state given by the functional form in appendix A.

Details on the selection of equilibrium property data and the fitting techniques developed are discussed in reference [99] and are not required for this paper.

3.1. Correlation Procedure

Our experience has indicated that the behavior of transport coefficients over a wide range of experimental conditions is dominated by their density dependence. Further-

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[6] The torsional viscometer consists of a cylindrical cut of piezoelectric material which can be driven in a torsional mode by the application of an alternating electric field. In the medium surrounding the crystal this twisting motion generates shear (viscous) waves which are very rapidly attenuated. Since an electrical circuit containing a piezoelectric crystal may be represented by an equivalent LCR resonant circuit, the damping of the fluid upon the crystal can be determined experimentally utilizing an impedance bridge and frequency control unit. Given a simple hydrodynamic theory, several expressions relating the product of the viscosity, η, and density, ρ, to measurable resonant parameters of the crystal may be derived.

critical point enhancement in the thermal conductivity coefficient. We are further grateful for his comments on the accuracy of the data in the literature. The opinions of D. E. Diller, L. Guildner, and H. M. Roder have also been very helpful. Finally, we thank Karen Bowie for her considerable help with the preparation of this paper.

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$$[\rho^{*2} K_T^{*}]^{-1} = |\Delta\rho^{*}|^{\delta-1}\left[\delta h(x) - \frac{x}{\beta} h'(x)\right],$$

with

$$h(x) = E_1\left(\frac{x+x_0}{x_0}\right)\left[1+E_2\left(\frac{x+x_0}{x_0}\right)^{2\beta}\right]^{\frac{\gamma-1}{2\beta}},$$

and $\qquad$ (21)

$$h'(x) = \frac{dh(x)}{dx} = \frac{E_1}{x_0}\left[1+E_2\left(\frac{x+x_0}{x_0}\right)^{2\beta}\right]^{\frac{\gamma-1}{2\beta}}$$

$$+\frac{\gamma-1}{x_0}E_1 E_2\left(\frac{x+x_0}{x_0}\right)^{2\beta}\left[1+E_2\left(\frac{x+x_0}{x_0}\right)^{2\beta}\right]^{\frac{\gamma-1-2\beta}{2\beta}}$$

where

$$\Delta\rho^{*} = |\rho-\rho_c|/\rho_c; \quad \Delta T^{*} = |T-T_c|/T_c;$$

$$\rho^{*} = \rho/\rho_c; \quad X = \Delta T^{*}/|\Delta\rho^{*}|^{1/\beta}; \quad K_T^{*} = P_c K_T. \tag{22}$$

We already have defined ρ_c and T_c; P_c is the critical pressure. The remaining parameters of equation (21) are defined in reference [103]. We will adopt equation (21) without further discussion on its derivation and background and refer to reference [103] for details. Values of the parameters of equation (21) are given in table 9.

TABLE 9. Critical point parameters

	Argon	Nitrogen	Oxygen
P_c (MPa)	4.8619	3.398	5.043
ρ_c (g/cm^3)	0.533	0.31406	0.4362
T_c (K)	150.725	126.15	154.575
x_0	0.1836	0.1836	0.1892
β	0.3574	0.3574	0.350
δ	4.35189	4.35189	4.30
E_1	2.396	2.396	2.0580
E_2	0.218	0.218	0.300
γ''	1.198	1.198	1.155

It turns out that they are close to being universal as far as can be determined at this time so the parameters used for nitrogen (and xenon and krypton) were the same as for argon [10].

The critical point excess, $\Delta\lambda_c$, was calculated from equation (13) with a compressibility obtained from the equation of state *unless*

$$\Delta\rho^{*} \leq 0.25 \text{ and } \Delta T^{*} \leq 0.025. \tag{23}$$

If the density and temperature satisfied equation (23), equation (21) was used.

The effect of substituting compressibilities from equation (21) into the general calculation for the excess $\Delta\lambda_c$ was assessed. As an example, figure 3 displays a graph of $\Delta\lambda_c(2)/\Delta\lambda_c(1)$ versus density for oxygen at 154.8 K ($\Delta T^{*} = 0.00146$). Values for $\Delta\lambda_c$ were determined via equation (21), given the label $\Delta\lambda_c(2)$ and also via the equation of state given the label $\Delta\lambda(1)$. Figure 3 illustrates two features: (a) A discontinuity naturally occurs at $\Delta\rho^{*} = 0.25$ but, in this example, it is only ~ 7 percent in the *critical excess*. The effect on the *total* thermal conductivity is much smaller ~ 1.5 percent. This percentage will be slightly higher as ΔT^{*} tends to zero but will decrease rapidly as ΔT^{*} increases. (b) As one can see, the use of an analytical equation of state will considerably underestimate K_T, and hence $\Delta\lambda_c$.

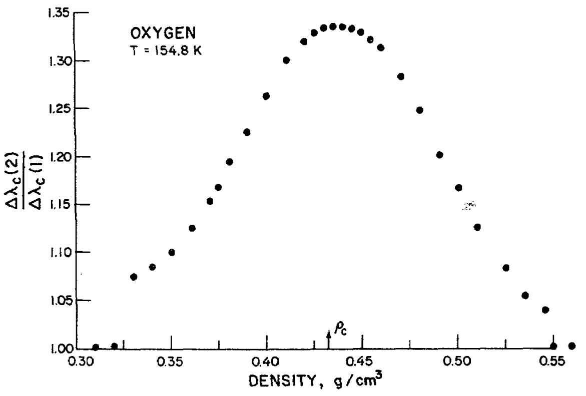

FIGURE 3. Comparison between critical excess thermal conductivity coefficients, $\Delta\lambda_c$, for oxygen calculated from the equation of state of reference [100] and from the scaling law equation of reference [108]. See the text.

Note on the Viscosity

The viscosity coefficient appears in equation (15) and there is evidence that the viscosity coefficient also may show an enhancement in the critical region [103] but, if it exists, it is not of the same magnitude as the corresponding enhancement in the thermal conductivity and is not considered here.

4. Summary of the Calculation Procedure

The transport properties of argon, nitrogen and oxygen were calculated as functions of temperature and density by adding the contributions from the dilute gas, approximate first density corrections, the remainders, $\Delta\lambda'(\rho,T)$ or $\Delta\eta'(\rho,T)$, and, for thermal conductivity, the critical excess. Transformation into pressure-temperature coordinates was achieved with the equation of state given in appendix A.

Krypton and Xenon

It was decided not to correlate data for these fluids because, on the one hand, reliable transport data are limited and, on the other hand, we do not have an equation of state for these fluids in an acceptable form. Thus we used the principle of corresponding states.[11] A reduced viscosity was defined as

$$\eta^{*} = \eta\sigma^2\left(\frac{N}{M}\right)^{1/2} k^{-1/2}\left(\frac{\epsilon}{k}\right)^{-1/2} \tag{24}$$

and a reduced thermal conductivity by

$$\lambda^{*} = \lambda\sigma^2\left(\frac{M}{N}\right)^{1/2}\left(\frac{\epsilon}{k}\right)^{-1/2} k^{-3/2} \tag{25}$$

The parameters, σ and ϵ/k, are associated with the m-6-8 pair potential. We have defined ϵ/k; σ follows from the

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[10] More recent work [109] indicates that this statement is only partially correct.

[11] The authors intend "the principle of corresponding states" to mean a general relationship between fluids and that the mathematical models of this principle used here are only approximating formuli (of which there are many).

relation, $\varphi(\sigma)=0$. Table 8 lists values. A reduced pressure is given by

$$P^* = P\sigma^3 \left[\left(\frac{\epsilon}{k}\right) k\right]^{-1} \tag{26}$$

and a reduced temperature has already been introduced by

$$T^* = T/(\epsilon/k) \tag{8}$$

To obtain the viscosity and thermal conductivity coefficients of krypton and xenon at a given temperature and pressure, a corresponding pressure and temperature was first found for argon via equations (26) and (8). The argon equation of state was used to find the density, then the transport coefficients were determined via equations (24) and (25).

Clearly we have assumed that the principle of corresponding states is valid for argon, krypton, and xenon. This assumption appears justified for the transport properties at low densities; see, for example, reference [110, 111]. Further, it has been concluded that the *m*-6-8 potential can provide satisfactory reducing parameters [112]. Notice for instance, that table 8 shows that m and γ' are the same for argon, krypton, and xenon. Hence, it is correct to write $\varphi=\epsilon f(\sigma)$ where $f(\sigma)$ is the same function for all three elements. It is less clear how well equilibrium properties correspond but Streett's recent work [113] suggests that the principle is valid provided a proper choice of reducing parameters is made.

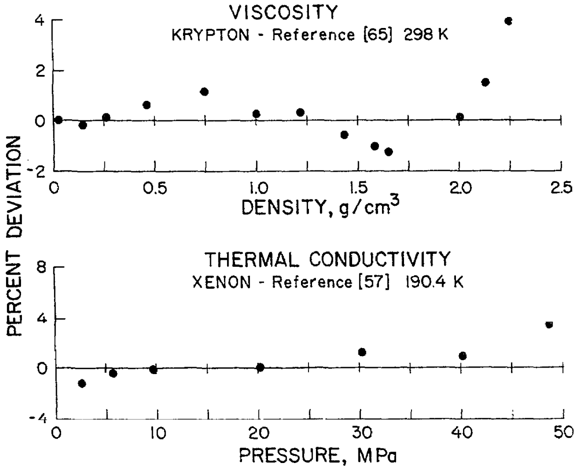

FIGURE 4. Deviations between representative viscosity and thermal conductivity coefficients, calculated via the principle of corresponding states, and experiment.

Sample deviation curves for the viscosity of krypton [65] and the thermal conductivity of xenon [57] are given in figure 4. These curves illustrate typical maximum percentage deviations between the calculated and experimental values.

5. Deviations and Tables

In this section we present deviations between experiment and the correlation, together with tables of values of the *viscosity and thermal conductivity coefficients.*

Figure 5 shows the deviations for the viscosity at the saturated liquid boundary for argon, nitrogen and oxygen. Figures 6–14 display deviations for viscosity isotherms for these fluids. Deviations for low temperature thermal conductivity coefficients have been tabulated in tables 10–13, while the higher temperature thermal conductivities are represented in figures 15–17. In every case, the percent deviation has been defined as

$$\text{percent deviation} = \frac{(\text{expt.}-\text{calc.})}{\text{expt.}} 100. \tag{27}$$

Since the form of the correlation function is independent of the fluid for either the viscosity or thermal conductivity coefficient, we have presented curves for all fluids under roughly equivalent experimental conditions. In this way systematic differences between calculation and experiment can be better assessed. Further, it is also advantageous to examine systematic differences by considering the viscosity and the thermal conductivity at the same time: *the functional forms proposed are so similar that any systematic failure should be apparent in the deviation patterns for both properties.*

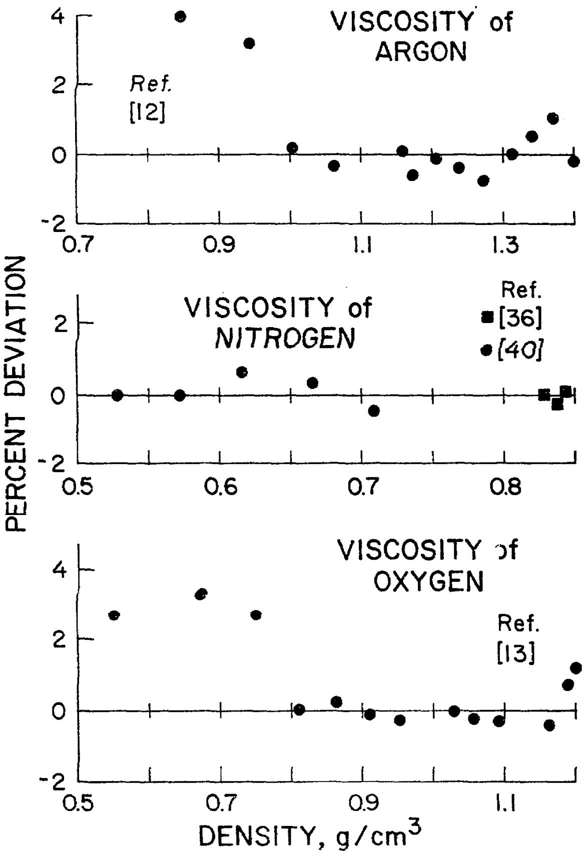

FIGURE 5. Deviations between experiment and calculation for the saturated liquid viscosity of argon, nitrogen and oxygen.

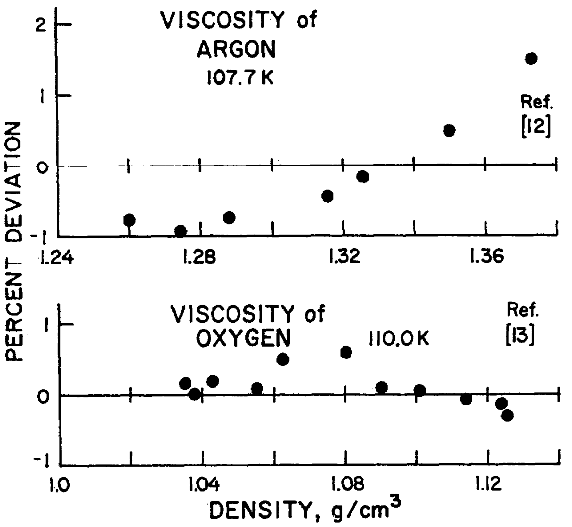

FIGURE 6. Viscosity deviation plots at ~ 110 K.

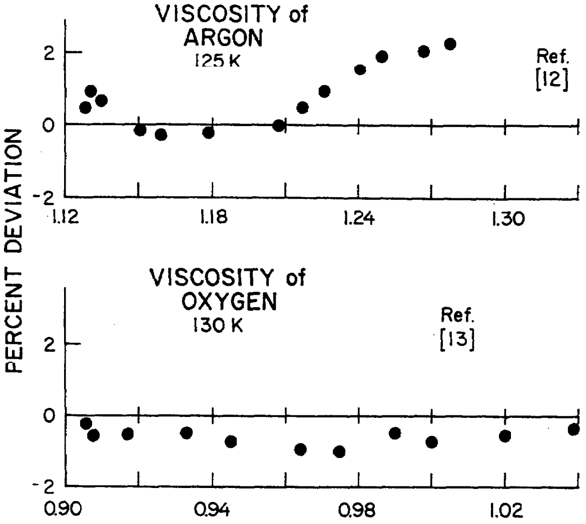

FIGURE 7. Viscosity deviation plots at ~ 125 K.

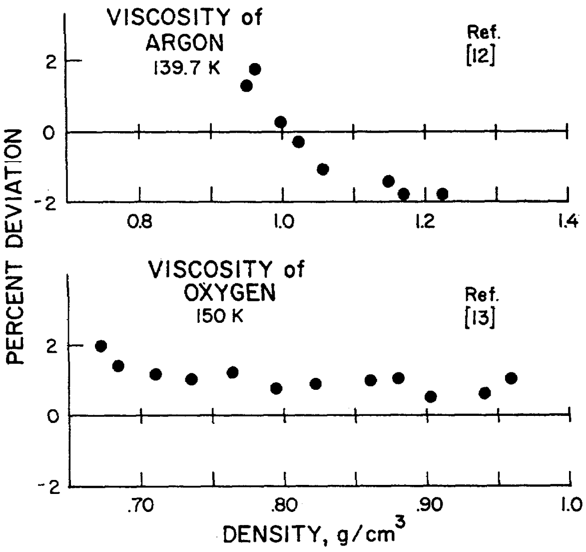

FIGURE 8. Viscosity deviation plots at ~ 140 K.

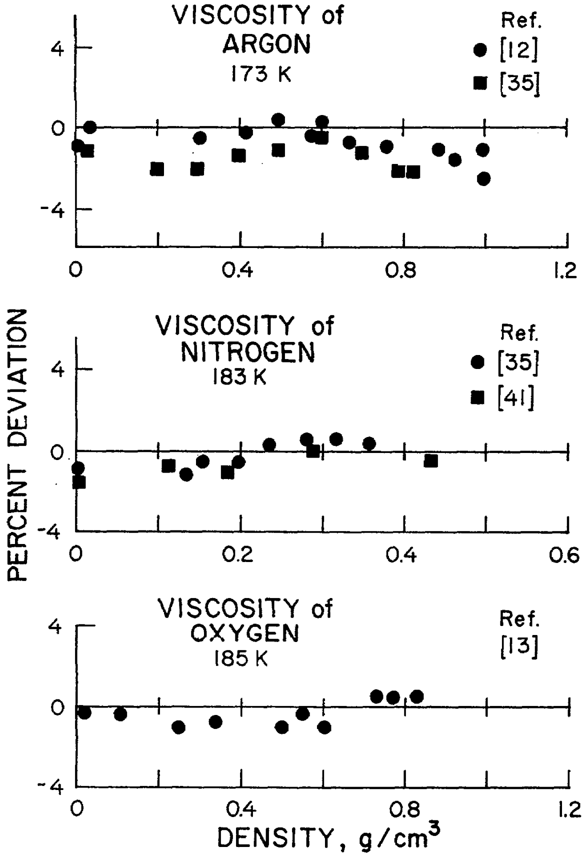

FIGURE 9. Viscosity deviation plots at ~ 180 K.

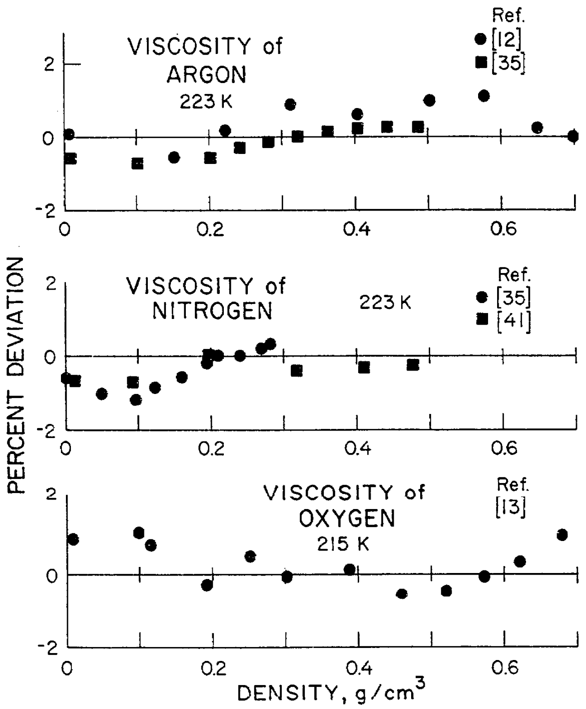

FIGURE 10. Viscosity deviation plots at ~ 220 K.

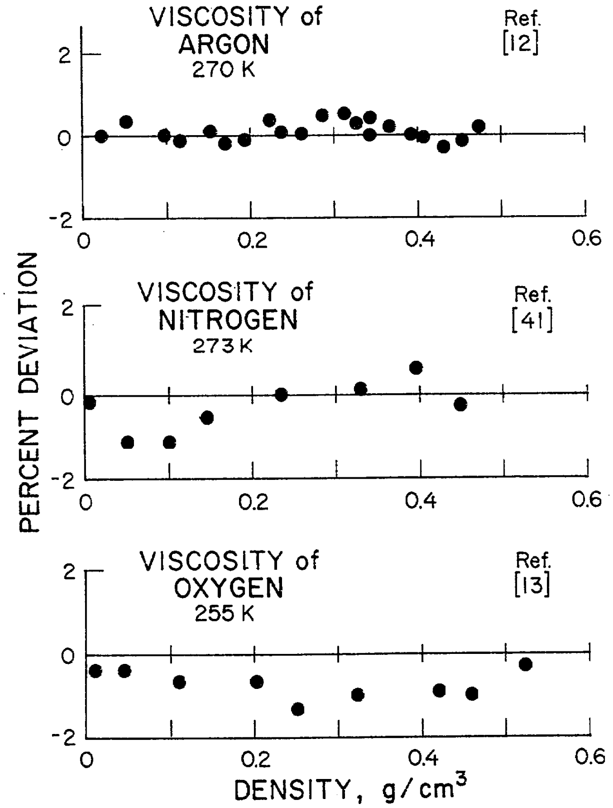

FIGURE 11. Viscosity deviation plots at ~ 270 K.

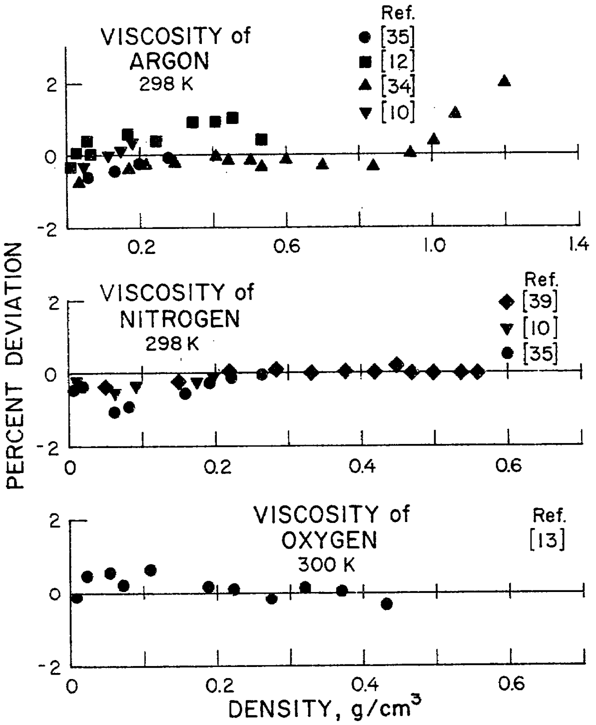

FIGURE 12. Viscosity deviation plots at ~ 300 K. Note that the argon deviation does appear to be systematic, but at a high density.

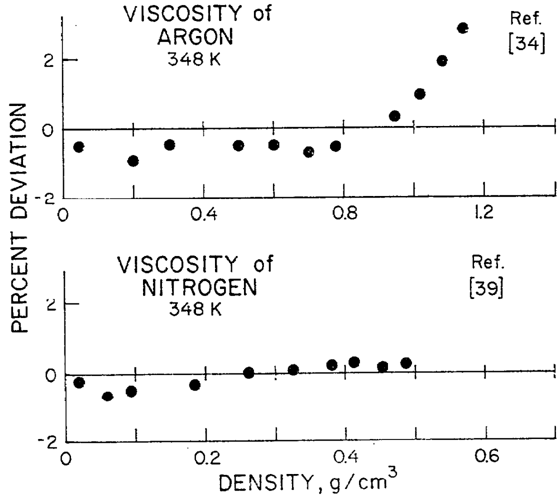

FIGURE 13. Viscosity deviation plots at 348 K.

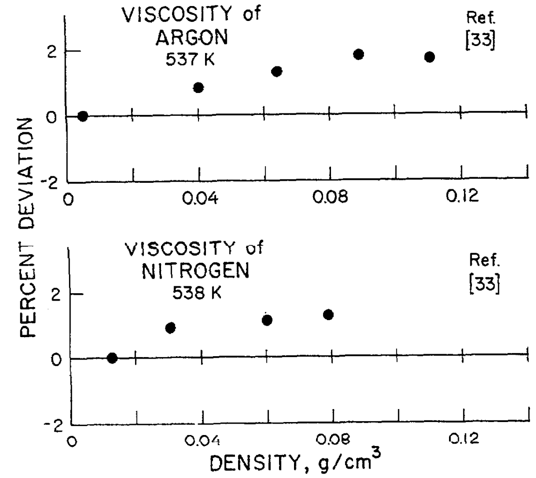

FIGURE 14. Viscosity deviation plots at ~ 537 K. Note that the density range covered is small.

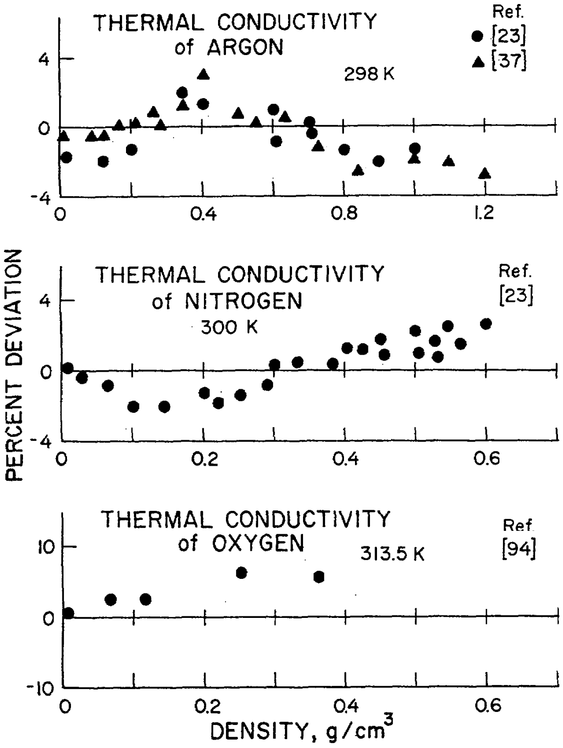

FIGURE 15. Thermal conductivity deviation curves at ~ 300 K.

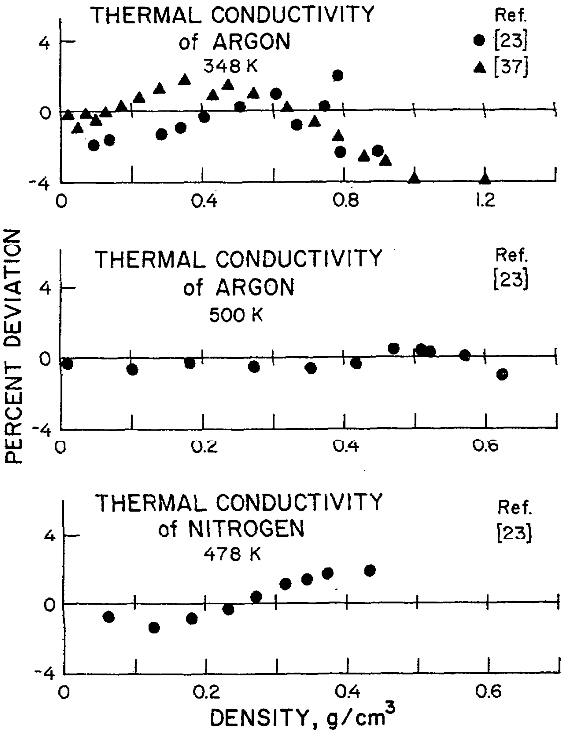

FIGURE 16. Thermal conductivity deviation curves at 348–500 K.

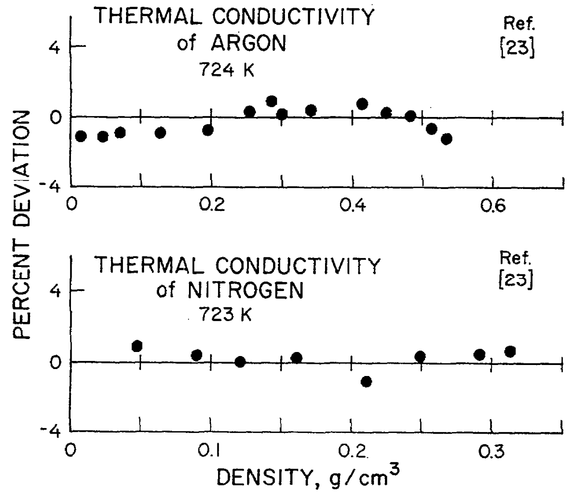

FIGURE 17. Thermal conductivity deviation curves at ~ 724 K.

TABLE 10. Percentage deviations between experimental data from reference [38] and the correlation for the thermal conductivity of argon. Data close to the critical point have been excluded.

Density g/cm^3	Temperature K	Percent deviation	Density g/cm^3	Temperature K	Percent deviation
1.3579	93.6	–0.93	1.1149	133.7	–0.52
1.3622	93.6	–0.52	1.1346	133.7	–0.25
1.3715	93.4	0.05	1.0308	136.5	0.31
1.3871	93.3	–0.01	0.9969	139.2	–3.45
1.3792	93.4	–0.11	1.0061	138.6	–1.26
1.3941	93.3	1.22	1.0474	138.3	–1.10
1.3290	98.0	–0.03	1.0768	138.2	–1.74
1.3337	98.0	0.33	1.1000	138.2	–2.97
1.3434	97.9	0.27	1.1164	136.1	–1.64
1.3525	97.8	0.63	1.0634	142.7	–3.62
1.3611	97.7	0.68	0.9501	142.5	–2.83
1.3693	97.6	1.12	0.9499	150.7	–2.42
1.2723	106.1	0.87	0.9318	152.2	0.92
1.2782	106.1	1.15	0.9241	152.9	–2.69
1.2932	105.5	0.72	0.9611	153.8	–1.24
1.2888	106.2	1.51	0.9508	154.8	–2.44
1.3003	104.5	1.82	0.9017	159.3	–2.02
1.3012	105.9	1.87	0.2168	161.7	4.69
1.3001	107.6	1.86	0.2173	161.6	3.50
1.3218	105.6	2.75	0.8438	164.1	0.74
1.3102	107.5	2.55	0.7416	164.5	1.84
1.2388	111.1	1.21	0.6911	175.2	3.33
1.2507	111.6	–0.26	0.7138	173.6	2.26
1.2194	115.9	1.12	0.1744	176.0	–0.43
1.2340	115.8	1.88	0.1734	174.9	–2.54
1.2463	115.8	1.24	0.1625	181.8	–2.47
1.2472	115.7	2.35	0.1549	184.5	–1.79
1.1900	117.2	2.65	0.4144	185.5	4.07
1.2024	116.1	0.65	0.5661	183.9	5.63
1.2334	117.7	–0.10	0.5812	183.5	3.32
1.2386	118.8	0.43	0.4730	194.5	3.05
1.1117	125.7	1.61	0.4786	193.8	2.96
1.1109	126.3	–0.37	0.3466	195.6	–3.64
1.1660	122.6	–1.23	0.3564	193.8	1.48
1.1367	126.1	–0.01	0.3452	195.4	0.35
1.1558	126.2	–0.02	0.1416	195.7	–2.77
1.1921	125.7	0.24			
1.1509	129.1	1.25			
1.0622	133.8	–2.54			
1.0908	133.8	–1.33			

TABLE 11. Percentage deviations between the data of reference [38] and [42] and the thermal conductivity correlation for nitrogen. Data close to the critical point have been excluded.

Reference	Density g/cm^3	Temperature K	Percent deviation
38	0.5504	126.8	–3.33
38	0.5951	126.6	–4.50
38	0.6247	126.3	–3.49
42	0.1390	132.6	0.00
38	0.0510	133.4	–3.85
38	0.1200	138.3	–2.54
38	0.1019	147.0	–1.42
38	0.3250	145.1	6.59
38	0.4633	145.1	–0.36
42	0.1073	143.4	–5.23
38	0.5239	144.8	0.61
38	0.0172	172.2	1.00
38	0.0356	172.0	–1.42
38	0.0763	171.6	–2.67
38	0.1773	171.1	–3.01
38	0.2890	170.9	0.32
38	0.3784	170.5	–1.50
42	0.0914	154.2	–8.49
38	0.0189	158.5	1.29
38	0.0396	158.3	–2.22
38	0.0883	157.6	–3.78
38	0.1516	156.9	–2.97
38	0.2370	155.3	2.29
38	0.3834	155.2	2.02
38	0.4643	154.9	–3.20
38	0.0758	164.2	–2.67
42	0.1835	169.0	–0.61
42	0.1518	184.3	–4.31
38	0.0156	187.9	1.10
38	0.0321	187.4	–0.38
38	0.0616	188.8	–2.09
38	0.0671	187.3	–2.02
38	0.1476	186.5	–4.26
38	0.2356	185.8	–1.26
38	0.3150	185.5	–0.96
38	0.0145	201.9	1.95
38	0.0294	201.8	–0.19
38	0.0562	202.5	–1.72
38	0.0608	201.5	–1.59
38	0.1294	201.0	–3.28
38	0.2021	200.5	–3.12
38	0.2692	200.8	–1.66
42	0.8135	76.4	2.36
42	0.8182	76.6	1.28
42	0.8240	76.9	1.90
42	0.8093	77.2	0.93
42	0.7968	83.3	1.51
42	0.7628	88.7	1.81
42	0.7681	89.8	1.41
42	0.7389	91.8	0.47
42	0.7191	97.3	0.14
38	0.7411	98.2	–1.26
38	0.7282	98.3	–1.19
38	0.7533	97.9	–0.48
42	0.7163	100.7	0.82
38	0.6571	105.8	–3.89
38	0.6697	105.8	–2.91
38	0.7072	105.6	–1.54
38	0.6799	105.9	–2.36
38	0.7216	105.4	–1.48
42	0.6643	107.2	1.28
42	0.6341	111.0	–0.56
42	0.6400	114.5	–1.79
38	0.6059	114.6	–3.11
38	0.6548	116.1	–2.58
38	0.6280	116.4	–3.28
38	0.6116	116.4	–3.96
38	0.6812	114.5	–4.42
38	0.5441	120.6	–0.68
42	0.5298	121.6	3.65
42	0.5486	121.3	3.78
38	0.0577	124.7	–0.21
38	0.4855	124.1	5.97
38	0.4855	124.1	6.31
38	0.4831	124.2	5.25
38	0.5233	125.9	–2.97
42	0.5469	127.2	2.39
38	0.5095	127.0	–3.34

TABLE 11. Percentage deviations between the data of reference [38] and [42] and the thermal conductivity correlation for nitrogen. Data close to the critical point have been excluded.—Continued

Reference	Density g/cm^3	Temperature K	Percent deviation
38	0.4898	128.4	−1.48
38	0.4821	128.9	2.50
38	0.4723	129.5	3.20

TABLE 12. Deviations between the thermal conductivity data of oxygen [43] and the correlation

Density g/cm^3	Temperature K	Percent deviation	Density g/cm^3	Temperature K	Percent deviation
1.2027	79.2	−2.45	0.7010	151.0	−1.17
1.1927	79.7	−2.14	0.7796	158.0	0.15
1.1945	79.7	−2.56	0.7039	158.7	−3.14
1.1963	79.8	−0.87	0.2096	158.9	4.87
1.1966	79.8	−0.89	0.6240	159.3	−1.25
1.2035	79.8	0.97	0.2021	159.9	0.19
1.1958	80.7	−0.22	0.2419	164.6	−0.40
1.2079	80.8	1.22	0.2866	165.1	2.73
1.1943	81.0	1.03	0.6958	167.1	−2.56
1.1997	82.9	0.57	0.2489	168.5	−2.24
1.1825	83.6	−0.64	0.2803	169.5	1.66
1.1371	92.3	0.89	0.0663	169.9	−3.62
1.1254	93.5	−0.48	0.2367	170.1	−2.59
1.1223	94.1	−0.17	0.0039	170.2	2.97
1.1141	101.7	4.60	0.1693	172.5	−6.85
1.1040	102.3	3.64	0.1675	173.1	−6.13
1.0816	102.4	0.00	0.2829	173.3	5.46
1.0770	102.7	−0.30	0.6255	173.7	0.39
1.0937	103.1	3.32	0.1481	175.0	−8.29
1.0774	104.0	0.30	0.3679	194.8	−0.19
1.0787	104.8	2.10	0.0034	196.1	1.74
1.0548	109.2	2.37	0.4393	196.9	1.58
0.9901	118.0	−1.60	0.3894	197.0	0.26
0.9968	118.2	−1.11	0.1108	197.3	−3.11
0.9689	124.0	−0.22	0.2715	197.4	−1.58
1.0012	124.4	6.22	0.1817	197.9	−3.57
0.8951	134.3	0.79	0.1098	198.4	−2.23
0.9156	136.2	1.36	0.0020	199.0	2.53
0.8080	141.1	−5.26	0.1790	199.2	−4.37
0.7937	144.9	−5.71	0.0502	199.8	−1.28
0.7658	147.1	−0.92			
0.8221	148.6	−1.48			
0.7863	148.8	−3.70			
0.8475	149.3	4.74			

TABLE 13. Deviations between experimental and calculated thermal conductivity coefficients for argon and nitrogen in the critical region.

Reference	T K	P MPa	ΔT^*	$\Delta\rho^*$	Percent deviation	$\Delta\lambda_c$ (calc.) mW·K^{-1}·m^{-1}
			Argon			
[38]	159.2	6.505	0.06	0.010	− 2.0	10.4
[38]	164.5	7.295	0.09	0.08	−10.2	7.6
[38]	164.7	7.295	0.09	0.09	0.0	7.5
[38]	159.2	7.295	0.06	0.28	− 2.6	7.5
[38]	159.0	7.295	0.06	0.29	− 2.7	7.4
[38]	149.2	4.864	0.01	0.45	9.0	6.4
[38]	149.2	4.864	0.01	0.45	− 3.4	6.4
			Nitrogen			
[38]	136.9	5.097	0.09	0.05	−13.0	8.6
[38]	136.2	5.097	0.08	0.003	3.0	8.1
[38]	139.0	5.097	0.10	0.17	− 8.0	7.2
[42]	142.1	6.809	0.13	0.17	− 1.8	5.9

Our conclusions from figures 5–17, and tables 10–13 are as follows:

1. With the exception of a few isolated datum points, experiment has been fitted to within the accuracies listed in tables 1–3. We consider this especially satisfactory in view of the wide temperature-density range considered and the relative simplicity of the correlation functions.
2. We observe only two experimental regions for which the correlation may give rise to systematic differences from experiment. Firstly, it is apparent that the viscosity coefficient is not properly fitted close to the critical point, and secondly, the correlation may fail at high densities for room temperature and above. However, with respect to the former, it is very difficult to measure the viscosity close to the critical point and incorrect density values could contribute to the deviations. Further, the deviations could be the result of an anomalous increase in the viscosity in the critical region. With respect to the latter, the densities and temperatures under which the correlation may fail correspond to very high pressures ($\sim$ 200 MPa) and we do not intend to present tables at such pressures. Again, however, it is not known if the experimental data, the densities, the correlating function, or a combination of these factors are responsible for the systematic deviations. Small systematic differences are sometimes observed at low densities but most probably occur because a datum point was not fitted if it was measured at a density less than $0.2\rho_c$; rather a given isotherm was extrapolated to the dilute gas value obtained from reference [1] or [2].
3. Figure 15 does dramatize the poor data situation for the thermal conductivity of oxygen. The data selected for room temperature are fitted only to within 7 percent. However, we feel the calculated values are reasonable and the figure, which is consistent with the 10 percent accuracy noted in table 3, gives a true reflection on the uncertainty in the data.

5.1. Thermal Conductivity in the Critical Region

As remarked previously, thermal conductivity data close to the critical point were not fitted. Instead, we have presented an expression (equation (13)) to predict the critical excess, $\Delta\lambda_c(\rho, T)$. In table 13, deviations are presented between the critical point data and our calculated values. Agreement is generally good but the data are limited. One should refer to reference [104] for a more complete assessment of our procedure for calculating the thermal conductivity coefficient in the critical region. In that paper predicted values were compared with experiment for the only fluid that has been studied in detail, carbon dioxide. [Also, but to a lesser extent, comparisons between calculation and experiment are discussed for methane.]

5.2. Calculation of Tables

Using the correlating functions described, the viscosity and thermal conductivity coefficients of argon, krypton, xenon, nitrogen, and oxygen were calculated and are given in tables 15–24. The coefficients are expressed as functions of pressure (MPa) and temperature (K). The viscosity unit is $\mu g \cdot cm^{-1} \cdot s^{-1}$ and the thermal conductivity unit is $mW \cdot m^{-1} \cdot K^{-1}$.

5.2.a. Remarks

The tables are presented in temperature and pressure coordinates but the correlations are based on the temperature-density behavior of the transport coefficients. Density is the dominant variable. We ensured, therefore, that an entry in the table would not require an extrapolation of the correlating equations beyond the range of data.

Argon and Nitrogen

For the tables given in the range 75–200 K for pressures to 50 MPa (~ 500 atmospheres), the density limit was selected as $2.63\rho_c$. Gaps in the tables indicate that this density would be exceeded. At the higher temperatures, 200–500 K, the pressure limit was extended to 100 MPa without reaching the upper density limit.

Oxygen

The tables for oxygen are calculated from 75–300 K for pressures to 35 MPa. The upper density selected was 2.79 ρ_c. The oxygen tables are not as extensive as their counterparts for argon and nitrogen because of the limited data coverage. Furthermore, we do not give thermal conductivity values at pressures exceeding 10 MPa for temperatures above 270 K because the data are apparently very poor in this region.

Krypton and Xenon

Tables for krypton and xenon were generated via the corresponding states procedure given in section 4. The limiting density chosen was $2.63\rho_c$, as for argon, but the tables were truncated at 20 MPa. We have been rather conservative, however, because there is no evidence that the principle of corresponding states fails at pressures exceeding 20 MPa.

For convenience, a table giving the transport properties of the saturated liquid, table 14, has been included for all fluids.

5.2.b. Uncertainty of the Tables and Extrapolation

Since—within the pressure-temperature limits of the tables—we are confident that the correlating procedure does not give rise to significant systematic deviations between calculation and experiment, an assessment of the uncertainty of the tabulated values can be based on the accuracy of the input data.

The percentage of uncertainty quoted in this paragraph and elsewhere in the paper are on a 2σ basis and are assessments of accuracy rather than precision. For the viscosity of argon, nitrogen and oxygen, we assign an uncertainty of ±2 percent to the tables. This assessment is increased to ±5 percent for krypton and xenon since the principle of corresponding states was used for these fluids. For all fluids, our estimate of uncertainties may be too low for viscosities extremely close to the critical point. The thermal conductivity of argon and nitrogen is believed to be reliable to ±4 percent, except for the following regions: (a) at pressures above 20 MPa and temperatures above 200K the uncertainty could be as much as 8 percent and (b) in the critical region ($T \pm 0.2T_c$ and $\rho \pm 0.4\rho_c$) an uncertainty of ±15 percent is assigned. However, it must be recalled that the data are very limited in this region, and very close to the critical point, the calculation becomes extremely sensitive to the determination of the compressibility, K_T, and the values selected for T_c and ρ_c. Further, the assignment of this percentage uncertainty is influenced by the differences between calculation and experiment we have observed for carbon dioxide (discussed in reference [104]). We have assumed, therefore, that similar behavior will be the case for the fluids here. For krypton and xenon, the limits are increased to ±6 percent overall and ±15 percent for the critical region. For temperatures up to 200 K, the accuracy on the thermal conductivity of oxygen is felt to be ±4 percent, but we set the uncertainty at ±8 percent for temperatures above 200 K because of the poor data situation. Again the values in the critical region are assessed at ±15 percent. Extrapolation of the tables is not recommended.

6. Conclusion

An empirical function to represent the viscosity and thermal conductivity coefficients of argon, nitrogen, and oxygen has been proposed. Based on our work with these fluids, and with others not specifically discussed (methane, carbon dioxide, fluorine) the functional form appears to be independent of the fluid. The viscosity equation differs from the thermal conductivity equation by an additive term which is necessary to account for the strong density dependence at high densities. The parameters of the function were determined by a least squares fit to carefully selected data and it was shown that the data can be represented within their estimated uncertainties. We also considered the critical region excess in the thermal conductivity coefficient.

Tables of values were generated for the fluids discussed above and for krypton and xenon. For the latter calculations, the principle of corresponding states was used. We ensured that the tabulated values were consistent with our equation of state for each fluid and that the values extrapolated to our estimates of the dilute gas coefficients.

This work has emphasized the need for reliable data in selected regions for the fluids discussed. In particular, the data coverage for oxygen is limited: viscosity measurements are required above room temperature and thermal conductivity measurements are needed above about 200 K.

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Appendix A. Equation of State

$$\begin{aligned}P = {} & \rho RT+\rho^2(N_1 T+N_2 T^{1/2}+N_3+N_4/T+N_5/T^2)\\ & +\rho^3(N_6 T+N_7+N_8/T+N_9/T^2)\\ & +\rho^4(N_{10} T+N_{11}+N_{12}/T)+\rho^5(N_{13})\\ & +\rho^6(N_{14}/T+N_{15}/T^2)+\rho^7(N_{16}/T)\\ & +\rho^8(N_{17}/T+N_{18}/T^2)+\rho^9(N_{19}/T^2)\\ & +\rho^3(N_{20}/T^2+N_{21}/T^3)\exp(-\gamma\rho^2)\\ & +\rho^5(N_{22}/T^2+N_{23}/T^4)\exp(-\gamma\rho^2)\\ & +\rho^7(N_{24}/T^2+N_{25}/T^3)\exp(-\gamma\rho^2)\\ & +\rho^9(N_{26}/T^2+N_{27}/T^4)\exp(-\gamma\rho^2)\\ & +\rho^{11}(N_{28}/T^2+N_{29}/T^3)\exp(-\gamma\rho^2)\\ & +\rho^{13}(N_{30}/T^2+N_{31}/T^3+N_{32}/T^4)\exp(-\gamma\rho^2).\end{aligned}$$

Table A-1. Parameters for the equation of state of argon
Units: P = atmospheres (1.01325×10^5 Pa = 1 atmosphere)
K = kelvin
ρ = moles per liter
Molecular weight = 39.948

$n_1 = 3.4342657242\times10^{-3}$
$n_2 = 5.7857036681\times10^{-2}$
$n_3 = -2.6982470812\times10^{0}$
$n_4 = 1.6481655285\times10^{2}$
$n_5 = -1.2849472420\times10^{4}$
$n_6 = -3.2636490894\times10^{-4}$
$n_7 = 2.4629470190\times10^{-1}$
$n_8 = -6.9585445697\times10^{1}$
$n_9 = 1.9196156939\times10^{4}$
$n_{10} = 1.6603909805\times10^{-5}$
$n_{11} = -1.0860316345\times10^{-2}$
$n_{12} = 3.3231759004\times10^{0}$
$n_{13} = 2.1776361947\times10^{-5}$
$n_{14} = 5.1615085812\times10^{-3}$
$n_{15} = -1.1366705407\times10^{0}$
$n_{16} = -2.9018517618\times10^{-4}$
$n_{17} = 3.7898289698\times10^{-6}$
$n_{18} = 1.1030489790\times10^{-3}$
$n_{19} = -1.4674092942\times10^{-5}$
$n_{20} = -1.1479610716\times10^{4}$
$n_{21} = -3.9393312963\times10^{5}$
$n_{22} = -9.9620084307\times10^{1}$
$n_{23} = -1.8575347046\times10^{4}$
$n_{24} = -2.9393483871\times10^{-1}$
$n_{25} = 1.6408588086\times10^{1}$
$n_{26} = -4.0447174229\times10^{-4}$
$n_{27} = -2.0820007165\times10^{0}$
$n_{28} = -5.4969320649\times10^{-7}$
$n_{29} = 7.5137405277\times10^{-5}$
$n_{30} = -2.8667425518\times10^{-10}$
$n_{31} = -6.3003722866\times10^{-8}$
$n_{32} = 2.5287413440\times10^{-6}$
$\gamma = -0.0056.$
$R = 0.08205616.$

Table A-2. Parameters for the equation of state of oxygen
Units: P = atmospheres (1.01325×10^5 Pa = 1 atmosphere)
K = kelvin
ρ = moles per liter
Molecular weight = 31.9988

$n_1 = -0.43090453911\times10^{-2}$
$n_2 = 0.35201737121\times10^{0}$
$n_3 = -0.58362214638\times10^{1}$
$n_4 = 0.24350908536\times10^{3}$
$n_5 = -0.12463611875\times10^{5}$
$n_6 = 0.12080882390\times10^{-3}$
$n_7 = -0.55031700313\times10^{-1}$
$n_8 = -0.10775785805\times10^{-3}$
$n_9 = 0.27853571320\times10^{4}$

Table A-2—Continued

$n_{10} = -0.70406316822\times10^{-5}$
$n_{11} = 0.73426722477\times10^{-2}$
$n_{12} = -0.59386982329\times10^{0}$
$n_{13} = -0.63616841908\times10^{-4}$
$n_{14} = 0.33034015638\times10^{-3}$
$n_{15} = -0.85769298838\times10^{-1}$
$n_{16} = 0.75461915984\times10^{-5}$
$n_{17} = 0.99643836109\times10^{-7}$
$n_{18} = 0.62468109855\times10^{-4}$
$n_{19} = -0.73169850036\times10^{-6}$
$n_{20} = 0.11734852208\times10^{4}$
$n_{21} = -0.39878103907\times10^{6}$
$n_{22} = -0.16682113989\times10^{2}$
$n_{23} = 0.10949860845\times10^{6}$
$n_{24} = -0.17843345856\times10^{-1}$
$n_{25} = 0.18752561979\times10^{1}$
$n_{26} = -0.94101785795\times10^{-4}$
$n_{27} = -0.57539681933\times10^{0}$
$n_{28} = -0.20715572396\times10^{-7}$
$n_{29} = 0.15747134549\times10^{-4}$
$n_{30} = -0.10757920925\times10^{-9}$
$n_{31} = -0.70023860092\times10^{-8}$
$n_{32} = 0.34354851874\times10^{-7}$
$\gamma = -0.0056.$
$R = 0.0820539.$

Table A-3. Parameters for the equation of state of nitrogen
Units: P = atmospheres (1.01325×10^5 Pa = 1 atmosphere)
K = kelvin
molecular weight = 28.016

$n_1 = 0.13622476927\times10^{-2}$
$n_2 = 0.10703246990\times10^{0}$
$n_3 = -0.24390072187\times10^{1}$
$n_4 = 0.34100744937\times10^{2}$
$n_5 = -0.42237430946\times10^{4}$
$n_6 = 0.10509860024\times10^{-3}$
$n_7 = -0.11259482652\times10^{-1}$
$n_8 = 0.14260078927\times10^{-2}$
$n_9 = 0.18469850160\times10^{5}$
$n_{10} = 0.81114008258\times10^{-7}$
$n_{11} = 0.23301164503\times10^{-2}$
$n_{12} = -0.50775258635\times10^{0}$
$n_{13} = 0.48502788193\times10^{-4}$
$n_{14} = -0.11365676411\times10^{-2}$
$n_{15} = -0.70743027354\times10^{0}$
$n_{16} = 0.75170664885\times10^{-4}$
$n_{17} = -0.11161411953\times10^{-5}$
$n_{18} = 0.36879656223\times10^{-3}$
$n_{19} = -0.20131769134\times10^{-5}$
$n_{20} = -0.16971744475\times10^{5}$
$n_{21} = -0.11971924004\times10^{6}$
$n_{22} = -0.97521827203\times10^{2}$
$n_{23} = 0.55463971315\times10^{5}$
$n_{24} = -0.17992045044\times10^{0}$
$n_{25} = -0.25658292607\times10^{1}$
$n_{26} = -0.41370771509\times10^{-3}$
$n_{27} = -0.25624541530\times10^{0}$
$n_{28} = -0.12422237374\times10^{-6}$
$n_{29} = 0.10355653584\times10^{-4}$
$n_{30} = -0.53869916655\times10^{-9}$
$n_{31} = -0.75741541283\times10^{-8}$
$n_{32} = 0.58536717206\times10^{-7}$
$\gamma = -0.0056.$
$R = 0.0820539.$

TABLE 14. Saturated liquid transport properties

T K	Density g/cm^3	λ mW•K^{-1}•m^{-1}	η μg•cm^{-1}•s^{-1}
	Argon		
T K	Density g/cm^3	λ mW•K^{-1}•m^{-1}	η μg•cm^{-1}•s^{-1}
85.0	1.4069	132.2	2778.
90.0	1.3762	123.5	2398.
95.0	1.3445	115.7	2089.
100.0	1.3113	108.6	1831.
105.0	1.2764	102.0	1612.
110.0	1.2396	95.7	1424.
115.0	1.2008	89.6	1260.
120.0	1.1594	83.7	1115.
125.0	1.1146	77.7	985.
130.0	1.0652	71.8	865.
135.0	1.0089	65.7	752.
140.0	0.9413	59.7	641.
145.0	0.8523	54.3	525.
150.0	0.6866	54.4	370.
	Krypton		
125.0	2.4025	91.1	3794.
135.0	2.3248	83.0	3117.
145.0	2.2419	75.9	2592.
155.0	2.1529	69.4	2172.
165.0	2.0566	63.1	1827.
175.0	1.9503	57.1	1534.
185.0	1.8289	51.0	1277.
195.0	1.6806	44.8	1037.
205.0	1.4721	39.1	790.
	Xenon		
170.0	2.8798	71.3	4683.
180.0	2.8123	66.6	4046.
190.0	2.7418	62.4	3523.
200.0	2.6677	58.4	3084.
210.0	2.5896	54.7	2709.
220.0	2.5069	51.1	2386.
230.0	2.4188	47.6	2102.
240.0	2.3234	44.2	1849.
250.0	2.2180	40.7	1617.
260.0	2.0976	37.2	1400.
270.0	1.9524	33.6	1187.
280.0	1.7585	30.5	962.
	Nitrogen		
70.0	0.8408	143.4	2037.
75.0	0.8193	137.0	1658.
80.0	0.7963	129.9	1377.
85.0	0.7719	122.3	1160.
90.0	0.7461	114.4	988.
95.0	0.7184	106.4	846.
100.0	0.6887	98.1	726.
105.0	0.6563	89.7	623.
110.0	0.6201	81.1	531.
115.0	0.5782	72.5	447.
120.0	0.5252	64.6	365.
125.0	0.4292	61.0	259.
	Oxygen		
75.0	1.2138	172.7	2867.
80.0	1.1904	166.1	2516.
85.0	1.1665	159.2	2215.
90.0	1.1420	152.1	1956.
95.0	1.1167	144.8	1734.
100.0	1.0907	137.6	1542.
105.0	1.0636	130.5	1375.
110.0	1.0354	123.6	1229.
115.0	1.0056	116.7	1100.
120.0	0.9739	110.0	985.
125.0	0.9398	103.4	880.
130.0	0.9025	96.8	784.
135.0	0.8609	90.2	695.
140.0	0.8130	83.6	609.
145.0	0.7552	77.3	523.

Table 15. Viscosity of Argon, μg/cm. 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
86	2695.	2710.	2728.	2746.	2764.	2781.				
90	74.6	2409.	2425.	2441.	2456.	2471.	2486.	2501.	2515.	2543.
95	78.5	2096.	2111.	2125.	2139.	2152.	2166.	2179.	2192.	2218.
100	82.4	1835.	1848.	1862.	1875.	1887.	1900.	1912.	1925.	1949.
105	86.3	1612.	1625.	1638.	1650.	1663.	1675.	1687.	1699.	1722.
110	90.2	92.3	1432.	1445.	1457.	1469.	1481.	1493.	1505.	1527.
115	94.2	96.1	1262.	1275.	1287.	1300.	1312.	1324.	1335.	1358.
120	98.1	100.0	103.0	1122.8	1135.	1148.	1161.	1173.	1185.	1208.
125	102.1	103.8	106.7	110.5	996.8	1010.	1024.	1037.	1050.	1074.
130	106.0	107.7	110.4	113.8	118.8	880.4	895.8	910.5	924.7	951.4
135	110.0	111.6	114.1	117.3	121.5	127.9	769.5	787.5	804.3	835.2
140	113.9	115.5	117.8	120.8	124.5	129.6	137.5	658.4	681.6	720.9
145	117.8	119.4	121.6	124.3	127.7	132.1	138.1	147.3	534.7	599.8
150	121.8	123.2	125.4	127.9	131.0	134.9	139.9	146.6	156.7	434.9
155	125.7	127.1	129.1	131.6	134.4	137.9	142.2	147.7	154.9	182.8
160	129.6	130.9	132.9	135.2	137.9	141.1	144.9	149.6	155.4	173.2
165	133.4	134.8	136.6	138.8	141.4	144.3	147.8	151.9	156.9	170.5
170	137.3	138.6	140.4	142.5	144.9	147.6	150.8	154.5	158.9	170.2
175	141.1	142.4	144.1	146.1	148.4	151.0	154.0	157.3	161.2	171.0
180	144.9	146.1	147.8	149.8	151.9	154.4	157.2	160.3	163.8	172.4
185	148.7	149.9	151.5	153.4	155.5	157.8	160.4	163.3	166.6	174.3
190	152.5	153.6	155.2	157.0	159.0	161.2	163.7	166.4	169.4	176.5
195	156.2	157.3	158.9	160.6	162.5	164.6	167.0	169.5	172.4	178.9
200	159.9	161.0	162.5	164.2	166.0	168.0	170.3	172.7	175.4	181.5
205	163.6	164.7	166.1	167.7	169.5	171.5	173.6	175.9	178.4	184.1
210	167.3	168.3	169.7	171.3	173.0	174.9	176.9	179.1	181.5	186.9
215	170.9	171.9	173.3	174.8	176.5	178.3	180.2	182.3	184.6	189.7
220	174.6	175.5	176.9	178.3	179.9	181.7	183.5	185.6	187.7	192.5
225	178.1	179.1	180.4	181.8	183.4	185.1	186.9	188.8	190.9	195.5
230	181.7	182.6	183.9	185.3	186.8	188.4	190.2	192.0	194.0	198.4
235	185.2	186.2	187.4	188.7	190.2	191.8	193.5	195.3	197.2	201.4
240	188.8	189.7	190.9	192.2	193.6	195.1	196.7	198.5	200.3	204.3
245	192.3	193.1	194.3	195.6	197.0	198.4	200.0	201.7	203.5	207.3
250	195.7	196.6	197.7	199.0	200.3	201.8	203.3	204.9	206.6	210.3
255	199.2	200.0	201.1	202.3	203.6	205.0	206.5	208.1	209.8	213.3
260	202.6	203.4	204.5	205.7	207.0	208.3	209.8	211.3	212.9	216.4
265	206.0	206.8	207.8	209.0	210.2	211.6	213.0	214.5	216.0	219.4
270	209.3	210.1	211.2	212.3	213.5	214.8	216.2	217.6	219.1	222.4
275	212.7	213.4	214.5	215.6	216.8	218.0	219.4	220.8	222.2	225.4
280	216.0	216.7	217.8	218.8	220.0	221.2	222.5	223.9	225.3	228.4
285	219.3	220.0	221.0	222.1	223.2	224.4	225.7	227.0	228.4	231.4
290	222.5	223.3	224.3	225.3	226.4	227.6	228.8	230.1	231.5	234.3
295	225.8	226.5	227.5	228.5	229.6	230.7	231.9	233.2	234.5	237.3
300	229.0	229.7	230.7	231.7	232.7	233.8	235.0	236.3	237.5	240.3
310	235.4	236.1	237.0	238.0	239.0	240.0	241.2	242.3	243.6	246.2
320	241.7	242.4	243.2	244.2	245.1	246.2	247.2	248.4	249.5	252.0
330	247.9	248.6	249.4	250.3	251.2	252.2	253.3	254.3	255.4	257.8
340	254.0	254.7	255.5	256.3	257.2	258.2	259.2	260.2	261.3	263.6
350	260.1	260.7	261.5	262.3	263.2	264.1	265.1	266.1	267.1	269.3
360	266.1	266.7	267.4	268.2	269.1	269.9	270.9	271.8	272.8	274.9

Table 15. (Cont.)

T,K	P, MPa 0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
370	272.0	272.5	273.3	274.0	274.9	275.7	276.6	277.5	278.5	280.5
380	277.8	278.3	279.1	279.8	280.6	281.4	282.3	283.2	284.1	286.0
390	283.5	284.1	284.8	285.5	286.3	287.1	287.9	288.8	289.7	291.5
400	289.2	289.8	290.4	291.1	291.9	292.7	293.5	294.3	295.2	297.0
410	294.8	295.4	296.0	296.7	297.4	298.2	299.0	299.8	300.6	302.4
420	300.4	300.9	301.5	302.2	302.9	303.7	304.4	305.2	306.0	307.7
430	305.9	306.4	307.0	307.7	308.4	309.1	309.8	310.6	311.3	313.0
440	311.3	311.8	312.4	313.1	313.7	314.4	315.1	315.9	316.6	318.2
450	316.7	317.2	317.8	318.4	319.0	319.7	320.4	321.1	321.9	323.4
460	322.0	322.5	323.1	323.7	324.3	325.0	325.6	326.3	327.1	328.6
470	327.3	327.7	328.3	328.9	329.5	330.2	330.8	331.5	332.2	333.6
480	332.5	332.9	333.5	334.1	334.7	335.3	335.9	336.6	337.3	338.7
490	337.7	338.1	338.6	339.2	339.8	340.4	341.0	341.7	342.3	343.7
500	342.8	343.2	343.7	344.3	344.9	345.5	346.1	346.7	347.3	348.7

T,K	P, MPa 6.0	7.0	8.0	9.0	10.0	15.0	20.0	30.0	40.0	50.0
90	2571.	2597.	2623.	2649.	2674.					
95	2243.	2267.	2291.	2314.	2337.	2445.	2544.			
100	1972.	1995.	2018.	2040.	2062.	2164.	2258.	2429.		
105	1745.	1767.	1789.	1810.	1831.	1930.	2021.	2186.	2335.	
110	1550.	1571.	1593.	1614.	1634.	1730.	1819.	1981.	2127.	2260.
115	1380.	1402.	1423.	1443.	1464.	1559.	1646.	1805.	1948.	2080.
120	1231.	1253.	1274.	1295.	1315.	1409.	1495.	1652.	1793.	1924.
125	1098.	1120.	1142.	1163.	1183.	1277.	1363.	1517.	1657.	1786.
130	976.5	1006.	1022.	1044.	1065.	1161.	1246.	1399.	1536.	1664.
135	863.3	889.3	913.6	936.6	958.5	1056.	1142.	1293.	1429.	1555.
140	754.5	784.3	811.5	836.6	860.1	962.2	1048.	1199.	1332.	1457.
145	645.2	682.0	713.7	742.2	768.1	876.2	964.5	1114.	1246.	1368.
150	525.3	577.5	617.5	651.2	680.8	797.2	888.0	1037.	1168.	1288.
155	352.0	461.8	519.2	561.7	596.8	724.3	818.2	968.8	1097.	1215.
160	213.3	321.6	414.4	472.0	515.2	656.8	754.3	906.0	1033.	1148.
165	193.5	238.1	313.0	383.7	436.5	594.4	695.9	848.8	974.5	1088.
170	186.9	213.2	255.3	311.0	365.5	537.2	642.5	796.7	921.2	1032.
175	184.4	203.3	230.6	267.8	311.6	485.7	594.1	749.2	872.5	982.1
180	183.7	198.8	218.8	245.2	277.5	440.3	550.3	705.9	828.0	935.7
185	184.2	196.7	212.7	232.9	257.4	401.6	511.3	666.6	787.3	893.2
190	185.3	196.1	209.5	225.8	245.3	369.8	476.9	630.9	750.1	854.1
195	186.8	196.4	207.9	221.7	237.8	344.6	447.0	598.6	716.2	818.2
200	188.7	197.3	207.5	219.4	233.2	325.1	421.2	569.6	685.2	785.3

Table 15. (Cont.)

	P, MPa									
T,K	6.0	7.0	8.0	9.0	10.0	20.0	30.0	50.0	75.0	100.0
200	188.7	197.3	207.5	219.4	233.2	421.2	569.6			
205	190.8	198.7	207.8	218.3	230.3	399.4	543.5			
210	193.1	200.3	208.6	218.0	228.7	381.0	520.2			
215	195.5	202.2	209.8	218.4	228.0	365.7	499.5			
220	198.0	204.3	211.3	219.2	227.9	353.1	481.0	678.4		
225	200.7	206.5	213.1	220.3	228.4	342.7	464.7	657.0		
230	203.3	208.8	215.0	221.8	229.2	334.2	450.2	637.4		
235	206.1	211.3	217.1	223.4	230.3	327.3	437.5	619.4		
240	208.8	213.8	219.2	225.2	231.7	321.7	426.2	602.9		
245	211.6	216.3	221.5	227.2	233.3	317.1	416.4	587.8		
250	214.5	219.0	223.9	229.2	235.0	313.5	407.7	574.0		
255	217.3	221.6	226.3	231.4	236.9	310.6	400.1	561.4		
260	220.2	224.3	228.8	233.6	238.8	308.3	393.5	549.9		
265	223.0	227.0	231.3	236.0	240.9	306.6	387.7	539.3	701.3	
270	225.9	229.7	233.9	238.3	243.1	305.4	382.7	529.6	687.7	
275	228.8	232.5	236.5	240.7	245.3	304.5	378.3	520.8	675.1	
280	231.7	235.3	239.1	243.2	247.5	304.0	374.6	512.7	663.4	
285	234.6	238.0	241.7	245.7	249.9	303.8	371.3	505.3	652.5	
290	237.5	240.8	244.4	248.2	252.2	303.8	368.6	498.5	642.4	
295	240.3	243.6	247.0	250.7	254.6	304.1	366.2	492.3	632.9	
300	243.2	246.4	249.7	253.3	257.0	304.6	364.2	486.7	624.1	
310	249.0	251.9	255.1	258.4	261.9	306.0	361.3	476.8	608.3	
320	254.7	257.5	260.5	263.6	266.9	307.9	359.4	468.6	594.5	710.2
330	260.3	263.0	265.8	268.8	271.9	310.4	358.4	461.8	582.5	693.7
340	266.0	268.5	271.2	274.0	277.0	313.1	358.1	456.2	572.1	679.1
350	271.6	274.0	276.6	279.3	282.1	316.1	358.5	451.6	563.0	666.1
360	277.1	279.5	281.9	284.5	287.1	319.4	359.4	448.0	555.1	654.6
370	282.6	284.9	287.2	289.7	292.2	322.8	360.6	445.1	548.3	644.4
380	288.1	290.2	292.5	294.8	297.3	326.4	362.3	442.9	542.4	635.3
390	293.5	295.6	297.7	300.0	302.3	330.1	364.2	441.3	537.3	627.3
400	298.9	300.9	302.9	305.1	307.4	333.9	366.4	440.2	532.9	620.2
410	304.2	306.1	308.1	310.2	312.4	337.8	368.8	439.6	529.2	613.8
420	309.5	311.3	313.3	315.3	317.3	341.8	371.5	439.3	526.0	608.2
430	314.7	316.5	318.4	320.3	322.3	345.8	374.2	439.5	523.4	603.3
440	319.9	321.6	323.4	325.3	327.2	349.8	377.1	439.9	521.2	598.9
450	325.0	326.7	328.5	330.3	332.1	353.9	380.2	440.6	519.4	595.1
460	330.1	331.7	333.4	335.2	337.0	358.0	383.3	441.5	518.0	591.7
470	335.2	336.8	338.4	340.1	341.9	362.2	386.5	442.7	517.0	588.8
480	340.2	341.7	343.3	345.0	346.7	366.3	389.8	444.1	516.2	586.3
490	345.2	346.6	348.2	349.8	351.5	370.5	393.2	445.7	515.8	584.1
500	350.1	351.5	353.0	354.6	356.2	374.6	396.6	447.4	515.6	582.3

Table 16. Thermal Conductivity of Argon, $mWK^{-1}m^{-1}$

	P, MPa									
T,K	0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
86	130.38	130.7	131.1	131.4	131.8	132.2				
90	6.01	123.7	124.1	124.5	124.9	125.2	125.6	125.9	126.3	126.9
95	6.29	115.9	116.3	116.7	117.1	117.4	117.8	118.1	118.5	119.2
100	6.58	108.7	109.1	109.5	109.9	110.3	110.7	111.1	111.4	112.1
105	6.87	102.0	102.4	102.8	103.3	103.7	104.1	104.5	104.8	105.6
110	7.17	7.90	96.01	96.47	96.93	97.37	97.81	98.24	98.66	99.48
115	7.47	8.14	89.71	90.23	90.74	91.23	91.72	92.19	92.65	93.55
120	7.77	8.40	9.33	84.02	84.60	85.17	85.72	86.25	86.77	87.78
125	8.07	8.65	9.50	10.59	78.35	79.03	79.68	80.30	80.90	82.06
130	8.37	8.92	9.70	10.65	11.99	72.61	73.41	74.17	74.90	76.27
135	8.67	9.19	9.91	10.77	11.88	13.61	66.68	67.67	68.59	70.28
140	8.98	9.46	10.13	10.91	11.88	13.21	15.47	60.58	61.84	64.01
145	9.28	9.74	10.37	11.08	11.94	13.04	14.63	17.41	54.63	57.55
150	9.58	10.01	10.60	11.27	12.04	12.99	14.24	16.06	19.12	51.21
155	9.88	10.29	10.85	11.46	12.17	13.00	14.04	15.41	17.36	25.67
160	10.18	10.57	11.10	11.67	12.31	13.06	13.95	15.05	16.49	21.16
165	10.48	10.85	11.35	11.88	12.48	13.15	13.92	14.85	15.99	19.24
170	10.78	11.13	11.60	12.10	12.65	13.26	13.95	14.74	15.68	18.16
175	11.07	11.41	11.86	12.33	12.84	13.40	14.02	14.71	15.51	17.49
180	11.37	11.69	12.11	12.56	13.04	13.56	14.12	14.73	15.42	17.07
185	11.66	11.97	12.37	12.80	13.25	13.73	14.24	14.80	15.41	16.81
190	11.95	12.25	12.64	13.04	13.46	13.91	14.39	14.89	15.44	16.67
195	12.24	12.53	12.90	13.28	13.68	14.10	14.55	15.02	15.52	16.62
200	12.53	12.81	13.16	13.53	13.91	14.31	14.72	15.16	15.62	16.62
205	12.82	13.08	13.42	13.78	14.14	14.52	14.91	15.32	15.75	16.67
210	13.10	13.36	13.69	14.02	14.37	14.73	15.11	15.50	15.90	16.76
215	13.38	13.63	13.95	14.28	14.61	14.96	15.31	15.68	16.06	16.86
220	13.66	13.91	14.21	14.53	14.85	15.18	15.52	15.87	16.23	16.99
225	13.94	14.18	14.47	14.78	15.09	15.41	15.73	16.07	16.41	17.14
230	14.22	14.45	14.74	15.03	15.33	15.64	15.95	16.27	16.60	17.29
235	14.50	14.72	15.00	15.28	15.57	15.87	16.17	16.48	16.79	17.45
240	14.77	14.98	15.26	15.53	15.81	16.10	16.39	16.69	16.99	17.62
245	15.04	15.25	15.51	15.78	16.05	16.33	16.61	16.90	17.19	17.80
250	15.31	15.52	15.77	16.03	16.29	16.56	16.84	17.11	17.40	17.98
255	15.58	15.78	16.03	16.28	16.54	16.80	17.06	17.33	17.60	18.17
260	15.85	16.04	16.28	16.53	16.78	17.03	17.29	17.55	17.81	18.36
265	16.11	16.30	16.54	16.78	17.02	17.26	17.51	17.77	18.02	18.55
270	16.37	16.56	16.79	17.02	17.26	17.50	17.74	17.98	18.23	18.74
275	16.64	16.81	17.04	17.27	17.50	17.73	17.97	18.20	18.45	18.94
280	16.89	17.07	17.29	17.51	17.74	17.96	18.19	18.43	18.66	19.14
285	17.15	17.32	17.54	17.76	17.97	18.20	18.42	18.65	18.87	19.34
290	17.41	17.57	17.79	18.00	18.21	18.43	18.65	18.87	19.09	19.54
295	17.66	17.83	18.03	18.24	18.45	18.66	18.87	19.09	19.30	19.75
300	17.91	18.07	18.28	18.48	18.68	18.89	19.10	19.31	19.52	19.95
310	18.41	18.57	18.76	18.96	19.15	19.35	19.55	19.75	19.95	20.36
320	18.90	19.05	19.24	19.43	19.62	19.81	20.00	20.19	20.38	20.77
330	19.39	19.53	19.71	19.89	20.08	20.26	20.44	20.63	20.81	21.19
340	19.87	20.01	20.18	20.36	20.53	20.71	20.88	21.06	21.24	21.60
350	20.34	20.48	20.65	20.81	20.98	21.15	21.32	21.50	21.67	22.01
360	20.81	20.94	21.10	21.27	21.43	21.60	21.76	21.93	22.09	22.43

Table 16. (Cont.)

T,K	P, MPa									
	0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
370	21.27	21.40	21.56	21.72	21.87	22.03	22.19	22.35	22.51	22.84
380	21.73	21.85	22.01	22.16	22.31	22.47	22.62	22.78	22.93	23.25
390	22.18	22.30	22.45	22.60	22.75	22.90	23.05	23.20	23.35	23.65
400	22.63	22.74	22.89	23.03	23.18	23.32	23.47	23.62	23.76	24.06
410	23.07	23.18	23.32	23.46	23.61	23.75	23.89	24.03	24.17	24.46
420	23.50	23.61	23.75	23.89	24.03	24.17	24.31	24.44	24.58	24.86
430	23.93	24.04	24.18	24.31	24.45	24.58	24.72	24.85	24.99	25.26
440	24.36	24.47	24.60	24.73	24.86	24.99	25.13	25.26	25.39	25.65
450	24.78	24.89	25.01	25.14	25.27	25.40	25.53	25.66	25.79	26.05
460	25.20	25.30	25.43	25.55	25.68	25.81	25.93	26.06	26.18	26.44
470	25.61	25.71	25.84	25.96	26.08	26.21	26.33	26.45	26.58	26.82
480	26.02	26.12	26.24	26.36	26.48	26.60	26.73	26.85	26.97	27.21
490	26.43	26.52	26.64	26.76	26.88	27.00	27.12	27.24	27.35	27.59
500	26.83	26.92	27.04	27.16	27.27	27.39	27.51	27.62	27.74	27.97

T,K	P, MPa									
	6.0	7.0	8.0	9.0	10.0	15.0	20.0	30.0	40.0	50.0
86										
90	127.6	128.2	128.8	129.3	129.9					
95	119.8	120.4	121.0	121.6	122.2	124.9	127.3			
100	112.8	113.5	114.1	114.7	115.4	118.2	120.8	125.2		
105	106.3	107.0	107.7	108.4	109.1	112.1	114.8	119.6	123.7	0.0
110	100.2	101.0	101.7	102.5	103.2	106.4	109.3	114.4	118.8	122.7
115	94.42	95.25	96.06	96.84	97.60	101.1	104.2	109.7	114.4	118.5
120	88.74	89.66	90.55	91.40	92.23	96.02	99.38	105.2	110.2	114.7
125	83.14	84.18	85.16	86.11	87.02	91.14	94.74	100.9	106.3	111.0
130	77.53	78.72	79.83	80.90	81.91	86.41	90.28	96.89	102.5	107.5
135	71.80	73.20	74.49	75.70	76.84	81.81	85.97	92.98	98.94	104.2
140	65.89	67.56	69.08	70.48	71.78	77.30	81.80	89.23	95.48	101.0
145	59.89	61.89	63.66	65.27	66.74	72.87	77.74	85.60	92.14	97.93
150	54.01	56.41	58.44	60.23	61.87	68.55	73.79	82.10	88.92	94.93
155	47.44	50.94	53.48	55.53	57.32	64.42	69.97	78.72	85.82	92.03
160	30.79	42.85	47.87	50.78	52.96	60.56	66.33	75.46	82.82	89.22
165	24.57	32.37	39.95	44.90	48.12	56.95	62.90	72.32	79.92	86.51
170	21.78	26.72	32.51	37.99	42.34	53.41	59.67	69.33	77.14	83.88
175	20.18	23.67	27.82	32.26	36.53	49.71	56.56	66.47	74.46	81.35
180	19.18	21.82	24.92	28.35	31.92	45.85	53.47	63.75	71.89	78.91
185	18.54	20.63	23.05	25.75	28.64	42.03	50.38	61.15	69.43	76.56
190	18.13	19.84	21.81	23.99	26.35	38.55	47.34	58.64	67.08	74.31
195	17.88	19.33	20.97	22.79	24.76	35.58	44.46	56.22	64.84	72.15
200	17.75	19.01	20.42	21.96	23.64	33.18	41.85	53.90	62.69	70.08

Table 16. (Cont.)

	P, MPa									
T,K	6.0	7.0	8.0	9.0	10.0	20.0	30.0	50.0	75.0	100.0
200	17.75	19.01	20.42	21.96	23.64	41.85	53.90			
205	17.69	18.81	20.05	21.40	22.86	39.55	51.72			
210	17.69	18.71	19.82	21.02	22.31	37.58	49.69			
215	17.73	18.67	19.68	20.76	21.92	35.91	47.82			
220	17.81	18.67	19.61	20.60	21.66	34.51	46.13	62.72		
225	17.90	18.72	19.58	20.50	21.48	33.34	44.59	61.11		
230	18.02	18.78	19.60	20.45	21.36	32.35	43.21	59.59		
235	18.14	18.87	19.64	20.44	21.29	31.53	41.97	58.16		
240	18.28	18.97	19.70	20.46	21.26	30.83	40.85	56.82		
245	18.43	19.09	19.78	20.50	21.25	30.24	39.85	55.56		
250	18.59	19.22	19.88	20.56	21.28	29.75	38.95	54.39		
255	18.75	19.36	19.98	20.64	21.32	29.32	38.15	53.29		
260	18.92	19.50	20.10	20.73	21.38	28.97	37.42	52.26		
265	19.09	19.65	20.23	20.83	21.45	28.67	36.78	51.30	66.25	
270	19.27	19.81	20.37	20.94	21.54	28.42	36.20	50.41	65.19	
275	19.45	19.97	20.51	21.06	21.63	28.21	35.68	49.57	64.18	
280	19.63	20.14	20.66	21.19	21.74	28.04	35.22	48.79	63.22	
285	19.82	20.31	20.81	21.33	21.86	27.90	34.81	48.07	62.31	
290	20.01	20.48	20.97	21.47	21.98	27.79	34.44	47.39	61.45	
295	20.20	20.66	21.13	21.62	22.11	27.70	34.11	46.77	60.63	
300	20.39	20.84	21.30	21.77	22.25	27.64	33.83	46.18	59.86	
310	20.78	21.20	21.64	22.08	22.53	27.57	33.35	45.13	58.43	
320	21.17	21.58	21.99	22.41	22.84	27.57	32.98	44.23	57.15	68.93
330	21.57	21.95	22.35	22.75	23.15	27.61	32.71	43.45	56.00	67.52
340	21.97	22.34	22.71	23.09	23.48	27.70	32.52	42.78	54.96	66.22
350	22.37	22.72	23.08	23.44	23.81	27.83	32.39	42.20	54.04	65.05
360	22.76	23.11	23.45	23.80	24.16	27.98	32.31	41.72	53.21	63.97
370	23.16	23.49	23.83	24.16	24.50	28.16	32.29	41.30	52.47	62.99
380	23.56	23.88	24.20	24.53	24.85	28.36	32.30	40.96	51.81	62.09
390	23.96	24.27	24.58	24.89	25.21	28.58	32.35	40.67	51.22	61.28
400	24.35	24.65	24.95	25.26	25.56	28.81	32.42	40.43	50.69	60.53
410	24.75	25.04	25.33	25.62	25.92	29.05	32.53	40.24	50.22	59.85
420	25.14	25.42	25.71	25.99	26.28	29.31	32.65	40.10	49.80	59.23
430	25.53	25.81	26.08	26.36	26.64	29.57	32.79	39.99	49.43	58.67
440	25.92	26.19	26.46	26.73	27.00	29.84	32.96	39.91	49.11	58.15
450	26.31	26.57	26.83	27.09	27.36	30.12	33.13	39.86	48.83	57.69
460	26.69	26.95	27.20	27.46	27.72	30.40	33.32	39.84	48.58	57.26
470	27.07	27.32	27.57	27.82	28.07	30.69	33.52	39.85	48.37	56.88
480	27.45	27.70	27.94	28.18	28.43	30.98	33.73	39.87	48.18	56.53
490	27.83	28.07	28.31	28.55	28.79	31.27	33.95	39.92	48.03	56.21
500	28.20	28.44	28.67	28.91	29.14	31.57	34.18	39.99	47.90	55.93

Table 17. Viscosity of Krypton, μg/cm. s

	P, MPa									
T,K	0.1	0.5	1.0	2.0	4.0	6.0	8.0	10.0	15.0	20.0
125	111.2	3810.	3832.	3874.	3955.	4031.	4104.			
130	115.4	3444.	3464.	3503.	3577.	3647.	3714.	3779.	3930.	
135	119.6	3125.	3144.	3180.	3249.	3316.	3379.	3440.	3584.	3717.
140	123.8	2844.	2861.	2896.	2962.	3026.	3087.	3146.	3284.	3412.
145	128.0	2593.	2610.	2643.	2708.	2769.	2829.	2886.	3020.	3145.
150	132.2	134.9	2384.	2417.	2480.	2540.	2598.	2654.	2786.	2908.
155	136.4	139.0	2179.	2212.	2275.	2335.	2392.	2447.	2576.	2696.
160	140.6	143.1	1993.	2025.	2088.	2148.	2205.	2259.	2387.	2506.
165	144.9	147.3	151.1	1854.	1918.	1978.	2035.	2089.	2216.	2334.
170	149.1	151.5	155.1	1694.	1760.	1821.	1879.	1934.	2061.	2177.
175	153.4	155.6	159.1	1543.	1613.	1676.	1735.	1791.	1919.	2035.
180	157.6	159.8	163.1	173.1	1474.	1541.	1602.	1659.	1788.	1904.
185	161.8	164.0	167.2	176.4	1340.	1412.	1476.	1535.	1667.	1784.
190	166.1	168.2	171.3	179.8	1207.	1288.	1357.	1419.	1555.	1672.
195	170.3	172.4	175.3	183.4	1071.	1166.	1243.	1309.	1450.	1569.
200	174.5	176.5	179.4	187.0	920.5	1044.	1132.	1204.	1351.	1473.
205	178.8	180.7	183.5	190.7	220.6	914.2	1021.	1102.	1259.	1384.
210	183.0	184.9	187.6	194.5	220.2	761.3	908.4	1002.	1171.	1300.
215	187.2	189.0	191.6	198.2	221.2	382.6	788.4	903.4	1087.	1221.
220	191.4	193.2	195.7	202.1	222.9	283.0	651.6	803.4	1007.	1146.
225	195.5	197.3	199.8	205.9	225.2	269.4	488.8	701.4	931.1	1076.
230	199.7	201.4	203.8	209.7	227.7	263.9	377.8	598.3	858.5	1010.
235	203.9	205.5	207.9	213.6	230.4	261.6	335.3	503.8	789.6	948.0
240	208.0	209.6	211.9	217.4	233.4	260.9	316.3	434.6	725.0	889.7
245	212.1	213.7	216.0	221.3	236.4	261.3	306.2	392.2	665.5	835.4
250	216.2	217.8	220.0	225.1	239.5	262.3	300.5	366.8	612.0	785.0
260	224.4	225.9	228.0	232.8	246.0	265.7	295.4	340.9	526.4	696.5
270	232.4	233.9	235.9	240.5	252.7	270.1	294.8	329.7	469.4	624.8
280	240.5	241.9	243.8	248.2	259.6	275.2	296.4	325.0	434.1	569.1
290	248.4	249.8	251.6	255.8	266.5	280.7	299.5	323.7	412.4	527.6
300	256.3	257.6	259.3	263.3	273.4	286.5	303.4	324.6	399.1	497.5
310	264.0	265.3	267.0	270.8	280.4	292.6	307.9	326.8	391.1	475.9
320	271.7	273.0	274.6	278.3	287.3	298.8	312.8	329.9	386.5	460.6
330	279.4	280.6	282.1	285.7	294.3	305.0	318.1	333.6	384.2	449.8
340	286.9	288.1	289.6	293.0	301.2	311.4	323.5	337.9	383.7	442.4
350	294.4	295.5	297.0	300.3	308.2	317.8	329.2	342.5	384.3	437.4
360	301.8	302.9	304.3	307.5	315.0	324.2	334.9	347.3	385.9	434.3
370	309.1	310.2	311.6	314.6	321.9	330.6	340.7	352.4	388.2	432.7
380	316.4	317.4	318.7	321.7	328.7	337.0	346.6	357.6	391.0	432.2
390	323.5	324.5	325.8	328.7	335.5	343.4	352.6	363.0	394.3	432.6
400	330.6	331.6	332.9	335.7	342.2	349.8	358.6	368.4	397.9	433.7
410	337.7	338.6	339.9	342.6	348.8	356.2	364.6	374.0	401.8	435.4
420	344.6	345.6	346.8	349.4	355.5	362.5	370.6	379.5	405.9	437.6
430	351.5	352.4	353.6	356.2	362.0	368.9	376.6	385.1	410.2	440.2
440	358.3	359.2	360.4	362.9	368.6	375.2	382.6	390.8	414.7	443.1
450	365.1	366.0	367.1	369.5	375.0	381.4	388.6	396.5	419.3	446.3
460	371.8	372.6	373.7	376.1	381.5	387.6	394.5	402.1	424.0	449.8
470	378.4	379.2	380.3	382.6	387.8	393.8	400.5	407.8	428.8	453.4
480	385.0	385.8	386.8	389.1	394.2	400.0	406.4	413.5	433.7	457.2
490	391.5	392.3	393.3	395.5	400.4	406.1	412.3	419.1	438.6	461.2
500	397.9	398.7	399.7	401.9	406.7	412.1	418.2	424.8	443.5	465.2

Table 18. Thermal Conductivity of Krypton, mWK^{-1}m^{-1}

	P, MPa									
T,K	0.1	0.5	1.0	2.0	4.0	6.0	8.0	10.0	15.0	20.0
125	4.25	91.23	91.47	91.93	92.82	93.64	94.42			
130	4.40	87.04	87.28	87.74	88.62	89.45	90.23	90.37	92.67	
135	4.55	83.14	83.38	83.85	84.75	85.59	86.39	87.15	88.90	90.49
140	4.70	79.46	79.71	80.19	81.12	81.99	82.82	83.61	85.42	87.07
145	4.85	75.94	76.20	76.71	77.67	78.59	79.45	80.27	82.17	83.89
150	5.00	5.48	72.82	73.35	74.37	75.33	76.24	77.10	79.10	80.90
155	5.15	5.60	69.52	70.09	71.18	72.19	73.15	74.06	76.16	78.06
160	5.31	5.73	66.28	66.90	68.06	69.15	70.17	71.13	73.35	75.34
165	5.46	5.86	6.45	63.74	65.00	66.17	67.26	68.29	70.63	72.73
170	5.61	6.00	6.54	60.57	61.96	63.23	64.41	65.50	67.99	70.20
175	5.77	6.13	6.65	57.35	58.91	60.31	61.59	62.77	65.42	67.75
180	5.92	6.27	6.76	8.07	55.82	57.38	58.79	60.07	62.90	65.37
185	6.08	6.41	6.87	8.06	52.62	54.41	55.98	57.38	60.43	63.04
190	6.23	6.55	6.99	8.09	49.26	51.36	53.14	54.69	57.99	60.76
195	6.39	6.69	7.11	8.13	45.69	48.22	50.25	51.99	55.57	58.52
200	6.55	6.84	7.23	8.19	41.87	44.98	47.32	49.27	53.18	56.32
205	6.70	6.98	7.36	8.26	12.15	41.71	44.40	46.56	50.81	54.15
210	6.85	7.13	7.49	8.34	11.53	38.43	41.56	43.93	48.48	52.02
215	7.01	7.27	7.62	8.42	11.16	40.34	38.79	41.41	46.23	49.94
220	7.16	7.42	7.75	8.51	10.93	19.12	35.77	38.99	44.08	47.93
225	7.32	7.56	7.88	8.61	10.77	16.32	31.29	36.43	42.05	46.01
230	7.47	7.71	8.01	8.70	10.67	14.91	25.20	33.33	40.10	44.17
235	7.62	7.85	8.15	8.81	10.60	14.04	21.16	29.58	38.13	42.42
240	7.78	8.00	8.28	8.91	10.57	13.44	18.76	25.88	36.05	40.71
245	7.93	8.14	8.42	9.02	10.55	13.02	17.21	22.93	33.84	39.01
250	8.08	8.28	8.55	9.13	10.56	12.72	16.13	20.76	31.53	37.28
260	8.38	8.57	8.82	9.36	10.62	12.34	14.79	17.99	27.16	33.74
270	8.68	8.86	9.10	9.59	10.73	12.17	14.05	16.43	23.74	30.36
280	8.98	9.15	9.37	9.83	10.87	12.12	13.66	15.53	21.38	27.46
290	9.27	9.43	9.64	10.08	11.04	12.15	13.47	15.01	19.82	25.19
300	9.56	9.72	9.92	10.33	11.22	12.23	13.39	14.73	18.79	23.48
310	9.85	10.00	10.19	10.58	11.42	12.35	13.40	14.58	18.11	22.23
320	10.14	10.28	10.46	10.83	11.62	12.49	13.45	14.52	17.64	21.30
330	10.42	10.56	10.73	11.08	11.84	12.65	13.54	14.51	17.33	20.61
340	10.70	10.83	11.00	11.34	12.05	12.82	13.65	14.55	17.12	20.09
350	10.98	11.10	11.26	11.59	12.27	13.00	13.78	14.62	16.98	19.70
360	11.25	11.37	11.53	11.84	12.49	13.18	13.92	14.71	16.90	19.40
370	11.52	11.64	11.79	12.09	12.72	13.38	14.07	14.81	16.86	19.18
380	11.79	11.91	12.05	12.34	12.94	13.57	14.24	14.94	16.86	19.02
390	12.06	12.17	12.31	12.59	13.17	13.77	14.40	15.07	16.88	18.90
400	12.33	12.43	12.57	12.84	13.39	13.97	14.58	15.21	16.93	18.83
410	12.59	12.69	12.82	13.08	13.62	14.18	14.76	15.36	16.99	18.79
420	12.85	12.95	13.07	13.33	13.85	14.39	14.94	15.52	17.08	18.78
430	13.10	13.20	13.32	13.57	14.07	14.59	15.13	15.69	17.17	18.79
440	13.36	13.45	13.57	13.81	14.30	14.80	15.32	15.86	17.28	18.82
450	13.61	13.70	13.82	14.05	14.53	15.01	15.51	16.03	17.39	18.87
460	13.86	13.95	14.06	14.29	14.75	15.22	15.71	16.21	17.52	18.93
470	14.11	14.20	14.31	14.53	14.98	15.43	15.90	16.38	17.65	19.01
480	14.35	14.44	14.55	14.76	15.20	15.64	16.10	16.57	17.79	19.10
490	14.60	14.68	14.78	15.00	15.42	15.85	16.30	16.75	17.93	19.19
500	14.84	14.92	15.02	15.23	15.64	16.07	16.50	16.93	18.08	19.30

Table 19. Viscosity of Xenon, μg/cm. s

T,K	P, MPa									
	0.1	0.5	1.0	2.0	4.0	6.0	8.0	10.0	15.0	20.0
170	135.4	4701.	4727.	4777.	4873.	4964.	5051.			
175	139.1	4363.	4387.	4433.	4523.	4608.	4689.	4768.		
180	142.9	4058.	4080.	4125.	4209.	4290.	4368.	4442.	4618.	4780.
185	146.6	3781.	3803.	3845.	3926.	4004.	4078.	4150.	4319.	4476.
190	150.4	3528.	3549.	3590.	3669.	3744.	3816.	3886.	4050.	4203.
195	154.1	3296.	3316.	3356.	3433.	3506.	3577.	3645.	3805.	3955.
200	157.9	161.1	3102.	3141.	3216.	3288.	3357.	3424.	3582.	3729.
205	161.7	164.8	2903.	2942.	3016.	3087.	3155.	3221.	3376.	3521.
210	165.4	168.5	2718.	2757.	2831.	2901.	2969.	3034.	3187.	3330.
215	169.2	172.2	2546.	2584.	2658.	2728.	2795.	2860.	3012.	3153.
220	173.0	175.9	180.5	2422.	2496.	2567.	2634.	2698.	2849.	2989.
225	176.8	179.7	184.1	2270.	2345.	2416.	2483.	2547.	2698.	2837.
230	180.6	183.4	187.6	2125.	2202.	2274.	2342.	2406.	2556.	2695.
235	184.4	187.1	191.2	1987.	2066.	2140.	2208.	2273.	2424.	2562.
240	188.2	190.9	194.9	1854.	1937.	2012.	2082.	2148.	2300.	2438.
245	192.0	194.6	198.5	209.8	1812.	1891.	1963.	2030.	2183.	2321.
250	195.8	198.4	202.1	212.8	1690.	1774.	1849.	1918.	2073.	2211.
255	199.6	202.1	205.8	215.9	1571.	1660.	1739.	1810.	1968.	2108.
260	203.4	205.9	209.4	219.1	1451.	1549.	1633.	1707.	1869.	2010.
265	207.2	209.6	213.1	222.3	1329.	1439.	1530.	1608.	1775.	1917.
270	211.0	213.3	216.7	225.6	1197.	1329.	1428.	1512.	1684.	1829.
275	214.8	217.1	220.4	228.9	265.3	1215.	1328.	1418.	1598.	1745.
280	218.6	220.8	224.0	232.3	264.4	1093.	1226.	1326.	1515.	1665.
285	222.3	224.5	227.7	235.7	264.8	951.9	1123.	1234.	1435.	1589.
290	226.1	228.3	231.4	239.1	265.9	731.9	1014.	1143.	1358.	1516.
295	229.9	232.0	235.0	242.5	267.5	349.4	895.6	1052.	1283.	1447.
300	233.6	235.7	238.7	246.0	269.4	329.5	756.6	958.6	1211.	1380.
310	241.1	243.1	246.0	252.9	273.9	316.7	468.3	763.9	1073.	1254.
320	248.5	250.5	253.2	259.8	279.0	313.5	390.7	581.3	945.1	1139.
330	255.9	257.8	260.5	266.7	284.5	313.8	367.8	477.3	828.0	1035.
340	263.3	265.1	267.7	273.7	290.3	316.0	358.4	431.8	726.5	941.1
350	270.6	272.4	274.8	280.6	296.2	319.3	354.6	409.8	645.3	858.2
360	277.9	279.6	282.0	287.5	302.2	323.2	353.8	398.4	585.7	786.8
370	285.1	286.8	289.1	294.4	308.3	327.7	354.7	392.3	544.2	727.1
380	292.2	293.9	296.1	301.3	314.5	332.5	356.9	389.5	515.9	678.6
390	299.4	301.0	303.2	308.1	320.7	337.6	359.8	389.7	496.6	640.0
400	306.4	308.0	310.1	314.9	327.0	342.8	363.3	389.4	483.3	609.8
410	313.5	315.0	317.1	321.7	333.3	348.2	367.2	391.0	474.2	586.4
420	320.4	321.9	323.9	328.4	339.6	353.8	371.5	393.4	468.1	568.4
430	327.4	328.8	330.8	335.1	345.9	359.4	376.0	396.3	464.2	554.6
440	334.2	335.7	337.6	341.8	352.1	365.0	380.8	399.7	461.9	544.0
450	341.1	342.5	344.3	348.4	358.4	370.7	385.7	403.4	460.9	536.0
460	347.8	349.2	351.0	355.0	364.7	376.5	390.7	407.4	460.9	530.0
470	354.6	355.9	357.7	361.6	370.9	382.3	395.8	411.6	461.6	525.6
480	361.2	362.5	364.3	368.1	377.1	388.1	401.0	416.0	462.9	522.6
490	367.9	369.1	370.8	374.5	383.3	393.8	406.2	420.5	464.8	520.6
500	374.4	375.7	377.3	380.9	389.5	399.7	411.5	425.2	467.1	519.5

Table 20. Thermal Conductivity of Xenon, $mWK^{-1}m^{-1}$

T,K	P, MPa 0.1	0.5	1.0	2.0	4.0	6.0	8.0	10.0	15.0	20.0
170	3.30	71.47	71.65	72.00	72.67	73.29	73.87			
175	3.39	69.04	69.21	69.56	70.22	70.84	71.43	71.38		
180	3.47	66.73	66.91	67.26	67.92	68.55	69.14	69.70	71.01	72.18
185	3.56	64.54	64.72	65.07	65.75	66.38	66.99	67.56	68.89	70.10
190	3.64	62.43	62.62	62.98	63.67	64.32	64.94	65.53	66.90	68.14
195	3.73	60.40	60.59	60.96	61.67	62.34	62.98	63.59	65.00	66.28
200	3.81	4.18	58.62	59.00	59.74	60.44	61.10	61.73	63.18	64.51
205	3.90	4.25	56.69	57.09	57.86	58.59	59.27	59.92	61.44	62.81
210	3.99	4.33	54.81	55.23	56.03	56.78	57.50	58.18	59.75	61.17
215	4.08	4.40	52.94	53.39	54.23	55.02	55.77	56.47	58.11	59.58
220	4.16	4.48	4.93	51.57	52.46	53.29	54.07	54.81	56.51	58.04
225	4.25	4.55	4.98	49.76	50.71	51.59	52.41	53.18	54.95	56.55
230	4.34	4.63	5.04	47.95	48.97	49.90	50.77	51.58	53.43	55.08
235	4.43	4.71	5.10	46.13	47.23	48.22	49.14	50.00	51.94	53.66
240	4.52	4.79	5.16	44.27	45.47	46.55	47.53	48.44	50.47	52.26
245	4.61	4.87	5.23	6.18	43.69	44.86	45.92	46.88	49.02	50.88
250	4.69	4.95	5.29	6.19	41.87	43.16	44.30	45.33	47.59	49.53
255	4.78	5.03	5.36	6.20	39.99	41.43	42.67	43.78	46.17	48.21
260	4.87	5.11	5.43	6.23	38.02	39.66	41.03	42.23	44.77	46.90
265	4.96	5.19	5.50	6.26	35.96	37.84	39.36	40.66	43.37	45.60
270	5.05	5.27	5.57	6.30	33.79	35.97	37.67	39.09	41.98	44.32
275	5.14	5.35	5.64	6.34	9.40	34.08	35.97	37.52	40.60	43.06
280	5.23	5.44	5.72	6.38	8.98	32.17	34.27	35.95	39.23	41.81
285	5.31	5.52	5.79	6.43	8.71	30.25	32.62	34.42	37.89	40.57
290	5.40	5.60	5.87	6.48	8.53	28.94	30.99	32.93	36.56	39.36
295	5.49	5.69	5.94	6.53	8.40	16.16	29.35	31.50	35.28	38.17
300	5.58	5.77	6.02	6.58	8.31	13.49	27.46	30.08	34.04	37.01
310	5.76	5.93	6.17	6.69	8.19	11.47	20.57	26.93	31.72	34.81
320	5.93	6.10	6.32	6.81	8.13	10.55	15.61	22.34	29.42	32.76
330	6.10	6.27	6.48	6.94	8.11	10.02	13.40	18.25	26.91	30.78
340	6.28	6.43	6.63	7.06	8.13	9.70	12.19	15.66	24.17	28.76
350	6.45	6.60	6.79	7.20	8.17	9.50	11.44	14.05	21.53	26.67
360	6.62	6.76	6.95	7.33	8.22	9.39	10.96	13.01	19.30	24.60
370	6.79	6.93	7.10	7.47	8.30	9.33	10.66	12.33	17.58	22.68
380	6.96	7.09	7.26	7.61	8.39	9.32	10.47	11.87	16.30	21.03
390	7.13	7.26	7.42	7.75	8.48	9.34	10.36	11.57	15.38	19.65
400	7.30	7.42	7.57	7.89	8.59	9.38	10.31	11.38	14.70	18.55
410	7.46	7.58	7.73	8.04	8.70	9.44	10.29	11.26	14.21	17.68
420	7.63	7.74	7.88	8.18	8.81	9.51	10.30	11.19	13.85	16.99
430	7.79	7.90	8.04	8.32	8.93	9.60	10.33	11.15	13.58	16.44
440	7.96	8.06	8.20	8.47	9.05	9.69	10.38	11.15	13.38	16.00
450	8.12	8.22	8.35	8.62	9.18	9.78	10.44	11.16	13.23	15.66
460	8.28	8.38	8.50	8.76	9.30	9.88	10.51	11.19	13.12	15.38
470	8.44	8.53	8.66	8.91	9.43	9.98	10.58	11.23	13.05	15.15
480	8.60	8.69	8.81	9.05	9.55	10.09	10.66	11.28	12.99	14.97
490	8.75	8.84	8.96	9.19	9.68	10.20	10.75	11.33	12.96	14.82
500	8.91	9.00	9.11	9.34	9.81	10.31	10.84	11.40	12.95	14.70

Table 21. Viscosity of Nitrogen, μg/cm. s

T,K	P, MPa 0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
75	1658.	1667.								
80	54.6	1384.	1395.	1405.	1415.	1425.	1435.	1445.	1455.	1475.
85	58.0	1165.	1176.	1186.	1196.	1206.	1215.	1225.	1235.	1254.
90	61.3	990.5	1000.	1010.	1021.	1030.	1040.	1050.	1060.	1078.
95	64.7	67.0	855.6	866.0	876.3	886.	895.3	906.1	915.8	934.8
100	68.0	70.2	731.3	742.3	753.1	763.7	774.0	784.1	794.1	813.4
105	71.3	73.4	76.8	633.2	645.0	656.4	667.4	678.2	688.7	708.9
110	74.6	76.6	79.7	532.4	546.2	559.2	571.6	583.5	595.0	616.7
115	77.9	79.8	82.6	86.5	449.6	466.4	481.7	495.8	508.9	533.3
120	81.2	82.9	85.5	89.0	93.9	103.3	388.8	408.7	425.9	455.4
125	84.4	86.1	88.5	91.6	95.7	101.8	113.8	301.0	335.2	378.3
130	87.6	89.2	91.5	94.3	97.9	102.7	109.7	122.8	173.3	292.8
135	90.8	92.3	94.5	97.1	100.3	104.3	109.7	117.3	129.8	195.2
140	93.9	95.4	97.5	99.9	102.8	106.4	110.8	115.5	124.2	152.5
145	97.0	98.4	100.4	102.7	105.4	108.6	112.4	117.0	122.9	140.4
150	100.1	101.5	103.4	105.5	108.0	110.9	114.3	118.3	123.1	136.1
155	103.2	104.5	106.3	108.3	110.7	113.3	116.4	119.9	124.0	134.5
160	106.2	107.5	109.2	111.1	113.3	115.8	118.6	121.8	125.4	134.3
165	109.2	110.4	112.1	113.9	116.0	118.3	120.9	123.8	127.1	134.8
170	112.1	113.3	114.9	116.7	118.7	120.9	123.3	125.9	128.9	135.8
175	115.1	116.2	117.8	119.5	121.3	123.4	125.7	128.2	130.9	137.1
180	118.0	119.1	120.6	122.2	124.0	126.0	128.1	130.4	132.9	138.7
185	120.8	121.9	123.3	124.9	126.6	128.5	130.5	132.7	135.1	140.4
190	123.7	124.7	126.1	127.6	129.3	131.0	133.0	135.0	137.3	142.2
195	126.5	127.5	128.8	130.3	131.9	133.6	135.4	137.4	139.5	144.1
200	129.2	130.2	131.5	133.0	134.5	136.1	137.9	139.7	141.7	146.1
205	132.0	133.0	134.2	135.6	137.1	138.6	140.3	142.1	144.0	148.1
210	134.7	135.7	136.9	138.2	139.6	141.1	142.7	144.5	146.3	150.2
215	137.4	138.3	139.5	140.8	142.2	143.6	145.2	146.8	148.5	152.3
220	140.1	141.0	142.1	143.4	144.7	146.1	147.6	149.2	150.8	154.4
225	142.7	143.6	144.7	145.9	147.2	148.6	150.0	151.5	153.1	156.5
230	145.3	146.2	147.3	148.5	149.7	151.0	152.4	153.9	155.4	158.7
235	147.9	148.7	149.8	151.0	152.2	153.5	154.8	156.2	157.7	160.8
240	150.5	151.3	152.3	153.5	154.6	155.9	157.2	158.5	160.0	163.0
245	153.0	153.8	154.8	155.9	157.1	158.3	159.5	160.8	162.2	165.1
250	155.5	156.3	157.3	158.4	159.5	160.7	161.9	163.2	164.5	167.3
255	158.0	158.8	159.8	160.8	161.9	163.0	164.2	165.4	166.7	169.5
260	160.5	161.2	162.2	163.2	164.3	165.4	166.5	167.7	169.0	171.6
265	163.0	163.7	164.6	165.6	166.6	167.7	168.8	170.0	171.2	173.8
270	165.4	166.1	167.0	168.0	169.0	170.0	171.1	172.3	173.4	175.9
275	167.8	168.5	169.4	170.3	171.3	172.3	173.4	174.5	175.6	178.1
280	170.2	170.9	171.7	172.7	173.6	174.6	175.7	176.7	177.8	180.2
285	172.5	173.2	174.1	175.0	175.9	176.9	177.9	179.0	180.0	182.3
290	174.9	175.6	176.4	177.3	178.2	179.1	180.1	181.2	182.2	184.4
295	177.2	177.9	178.7	179.6	180.5	181.4	182.4	183.4	184.4	186.5
300	179.5	180.2	181.0	181.8	182.7	183.6	184.6	185.5	186.5	188.6
310	184.1	184.7	185.5	186.3	187.2	188.0	188.9	189.9	190.8	192.8
320	188.6	189.2	190.0	190.7	191.5	192.4	193.2	194.1	195.1	197.0
330	193.0	193.6	194.3	195.1	195.9	196.7	197.5	198.4	199.2	201.1
340	197.4	198.0	198.7	199.4	200.1	200.9	201.7	202.5	203.4	205.1

Table 21. (Cont.)

	P, MPa									
T,K	0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
350	201.7	202.3	202.9	203.6	204.4	205.1	205.9	206.7	207.5	209.2
360	206.0	206.5	207.2	207.8	208.5	209.3	210.0	210.8	211.5	213.2
370	210.2	210.7	211.3	212.0	212.7	213.4	214.1	214.8	215.6	217.1
380	214.3	214.8	215.4	216.1	216.7	217.4	218.1	218.8	219.5	221.0
390	218.4	218.9	219.5	220.1	220.7	221.4	222.1	222.8	223.5	224.9
400	222.5	222.9	223.5	224.1	224.7	225.4	226.0	226.7	227.4	228.8
410	226.5	226.9	227.5	228.1	228.7	229.3	229.9	230.6	231.2	232.6
420	230.4	230.9	231.4	232.0	232.6	233.2	233.8	234.4	235.0	236.4
430	234.3	234.8	235.3	235.9	236.4	237.0	237.6	238.2	238.8	240.1
440	238.2	238.6	239.1	239.7	240.2	240.8	241.4	242.0	242.6	243.8
450	242.0	242.4	243.0	243.5	244.0	244.6	245.1	245.7	246.3	247.5
460	245.8	246.2	246.7	247.2	247.8	248.3	248.8	249.4	250.0	251.1
470	249.6	250.0	250.5	251.0	251.5	252.0	252.5	253.1	253.6	254.8
480	253.3	253.7	254.2	254.6	255.1	255.6	256.2	256.7	257.2	258.3
490	257.0	257.4	257.8	258.3	258.8	259.3	259.8	260.3	260.8	261.9
500	260.6	261.0	261.4	261.9	262.4	262.9	263.4	263.9	264.4	265.4

	P, MPa									
T,K	6.0	7.0	8.0	9.0	10.0	15.0	20.0	30.0	40.0	50.0
75										
80	1495.	1514.	1533.	1552.	1571.					
85	1273.	1292.	1310.	1329.	1347.	1434.	1518.			
90	1097.	1115.	1133.	1151.	1169.	1253.	1332.			
95	953.3	971.4	989.1	1006.	1023.	1105.	1181.	1324.		
100	832.2	850.4	868.2	885.5	902.5	982.5	1056.	1192.	1318.	
105	728.3	746.9	765.0	782.5	799.5	878.8	951.1	1082.	1202.	1315.
110	637.1	656.6	675.2	693.1	710.4	789.7	860.9	988.4	1103.	1211.
115	555.6	576.3	595.9	614.5	632.2	712.3	782.8	907.2	1018.	1121.
120	480.8	503.7	524.7	544.3	562.9	644.3	714.5	836.4	944.2	1043.
125	410.0	436.5	459.8	481.0	500.6	584.2	654.3	774.2	879.1	974.9
130	339.6	372.6	399.5	423.1	444.2	530.8	601.0	719.2	821.5	914.4
135	256.3	310.5	343.0	369.7	392.8	483.0	553.6	670.3	770.3	860.6
140	203.3	252.5	290.5	320.6	346.0	440.3	511.3	626.7	724.5	812.5
145	170.2	208.8	245.7	277.4	304.4	402.2	473.6	587.6	683.4	769.2
150	155.8	182.8	213.2	242.5	269.2	368.5	440.0	552.6	646.4	730.2
155	149.1	168.7	192.2	217.1	241.4	338.8	410.1	521.1	613.0	694.9
160	146.0	161.0	179.4	199.8	220.8	313.3	383.5	492.8	582.8	662.8
165	144.6	156.6	171.5	188.3	206.1	291.6	360.1	467.4	555.5	633.7
170	144.3	154.6	166.8	180.7	195.9	273.5	339.6	444.5	530.7	607.1
175	144.7	153.6	164.0	175.8	188.8	258.8	321.8	423.9	508.2	582.8
180	145.4	153.3	162.4	172.6	183.9	246.8	306.5	405.5	487.7	560.6
185	146.6	153.6	161.7	170.7	180.6	237.2	293.3	388.9	469.1	540.3
190	147.9	154.3	161.6	169.6	178.4	229.5	282.0	374.1	452.2	521.7
195	149.4	155.3	161.9	169.2	177.1	223.5	272.5	360.9	436.8	504.6
200	151.0	156.5	162.5	169.2	176.4	218.7	264.4	349.1	422.8	488.9

Table 21. (Cont.)

	P, MPa									
T,K	6.0	7.0	8.0	9.0	10.0	20.0	30.0	50.0	75.0	100.0
200	151.0	156.5	162.6	169.2	176.4	264.4	349.1			
205	152.7	157.8	163.5	169.6	176.2	257.7	338.6			
210	154.5	159.3	164.6	170.2	176.3	252.0	329.3			
215	156.4	160.9	165.8	171.1	176.8	247.2	321.0	449.2		
220	158.3	162.6	167.2	172.2	177.5	243.3	313.6	438.0		
225	160.3	164.3	168.7	173.3	178.3	240.0	307.1	427.8		
230	162.2	166.1	170.2	174.6	179.3	237.3	301.4	418.3		
235	164.2	167.9	171.8	176.0	180.5	235.2	296.3	409.7		
240	166.3	169.8	173.5	177.5	181.7	233.4	291.8	401.7		
245	168.3	171.7	175.2	179.1	183.1	232.1	287.9	394.3		
250	170.3	173.6	177.0	180.6	184.5	231.1	284.4	387.6		
255	172.4	175.5	178.8	182.3	185.9	230.3	281.4	381.4		
260	174.4	177.4	180.6	184.0	187.5	229.8	278.8	375.7		
265	176.5	179.4	182.5	185.7	189.0	229.5	276.6	370.5	478.6	
270	178.6	181.4	184.3	187.4	190.6	229.4	274.6	365.7	471.4	
275	180.6	183.3	186.2	189.2	192.3	229.5	272.9	361.3	464.6	
280	182.7	185.3	188.1	190.9	194.0	229.7	271.5	357.2	458.2	
285	184.7	187.3	189.9	192.7	195.7	230.1	270.4	353.5	452.2	
290	186.8	189.3	191.8	194.5	197.4	230.6	269.4	350.1	446.7	
295	188.8	191.2	193.7	196.4	199.1	231.1	268.6	347.0	441.4	
300	190.9	193.2	195.6	198.2	200.8	231.8	268.0	344.2	436.5	
310	194.9	197.2	199.5	201.9	204.4	233.4	267.3	339.3	427.6	
320	199.0	201.1	203.3	205.6	207.9	235.2	267.0	335.2	419.8	501.0
330	203.0	205.0	207.1	209.2	211.5	237.2	267.2	331.9	412.9	491.2
340	207.0	208.9	210.9	212.9	215.1	239.4	267.8	329.3	406.9	482.5
350	210.9	212.8	214.7	216.6	218.7	241.8	268.7	327.2	401.7	474.6
360	214.9	216.6	218.4	220.3	222.3	244.3	269.8	325.5	397.1	467.6
370	218.7	220.4	222.2	224.0	225.8	246.9	271.1	324.4	393.1	461.3
380	222.6	224.2	225.9	227.6	229.4	249.5	272.7	323.6	389.7	455.6
390	226.4	228.0	229.6	231.3	233.0	252.2	274.4	323.1	386.8	450.6
400	230.2	231.7	233.3	234.9	236.5	255.0	276.2	323.0	384.3	446.0
410	234.0	235.4	236.9	238.5	240.1	257.9	278.2	323.1	382.2	442.0
420	237.7	239.1	240.6	242.1	243.6	260.7	280.2	323.4	380.5	438.4
430	241.4	242.8	244.2	245.6	247.1	263.6	282.4	323.9	379.1	435.3
440	245.1	246.4	247.8	249.2	250.6	266.5	284.6	324.7	378.0	432.5
450	248.7	250.0	251.3	252.7	254.1	269.5	286.9	325.6	377.2	430.0
460	252.3	253.6	254.9	256.2	257.5	272.4	289.3	326.6	376.5	427.9
470	255.9	257.1	258.4	259.7	261.0	275.4	291.7	327.8	376.2	426.0
480	259.5	260.7	261.9	263.1	264.4	278.4	294.1	329.0	376.0	424.5
490	263.0	264.2	265.3	266.5	267.8	281.3	296.6	330.4	376.0	423.1
500	266.5	267.6	268.8	270.0	271.2	284.3	299.1	331.9	376.1	422.0

Table 22. Thermal Conductivity of Nitrogen, mWK^{-1}m^{-1}

	P, MPa									
T,K	0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
75	136.9	137.3								
80	7.81	130.2	130.7	131.1	131.6	132.1	132.6	133.0	133.5	134.4
85	8.27	122.6	123.2	123.7	124.3	124.8	125.4	125.9	126.4	127.5
90	8.73	114.6	115.3	115.9	116.6	117.2	117.9	118.5	119.1	120.3
95	9.18	10.29	107.1	107.8	108.6	109.3	110.1	110.8	111.5	112.9
100	9.64	10.65	98.53	99.4	100.3	101.2	102.1	102.9	103.7	105.3
105	10.09	11.03	12.55	90.63	91.73	92.79	93.81	94.79	95.75	97.57
110	10.55	11.42	12.77	81.17	82.59	83.92	85.17	86.37	87.51	89.66
115	11.00	11.82	13.04	14.72	72.71	74.48	76.10	77.60	79.00	81.59
120	11.46	12.23	13.35	14.79	16.97	22.06	66.71	68.63	70.37	73.47
125	11.92	12.64	13.68	14.95	16.68	19.51	26.49	60.00	62.08	65.74
130	12.37	13.06	14.02	15.16	16.61	18.66	22.02	28.97	48.40	58.27
135	12.82	13.47	14.37	15.41	16.66	18.29	20.57	24.03	29.70	46.14
140	13.27	13.89	14.73	15.68	16.79	18.14	19.87	22.19	25.37	34.96
145	13.72	14.31	15.10	15.97	16.97	18.12	19.52	21.25	23.43	29.43
150	14.17	14.73	15.47	16.29	17.19	18.20	19.37	20.75	22.39	26.59
155	14.61	15.14	15.85	16.61	17.44	18.35	19.36	20.51	21.82	25.00
160	15.04	15.56	16.23	16.95	17.71	18.54	19.44	20.43	21.53	24.09
165	15.48	15.97	16.61	17.29	18.01	18.77	19.59	20.47	21.42	23.57
170	15.91	16.38	17.00	17.64	18.31	19.03	19.78	20.58	21.43	23.30
175	16.34	16.79	17.38	17.99	18.63	19.30	20.00	20.74	21.51	23.19
180	16.76	17.20	17.76	18.35	18.95	19.59	20.25	20.94	21.65	23.18
185	17.18	17.60	18.15	18.71	19.29	19.89	20.52	21.16	21.83	23.25
190	17.59	18.00	18.53	19.07	19.63	20.20	20.80	21.41	22.04	23.36
195	18.00	18.40	18.91	19.43	19.97	20.52	21.08	21.66	22.26	23.51
200	18.40	18.79	19.29	19.79	20.31	20.84	21.38	21.93	22.50	23.68
205	18.81	19.18	19.66	20.15	20.65	21.16	21.68	22.21	22.75	23.87
210	19.20	19.57	20.03	20.51	20.99	21.48	21.98	22.49	23.01	24.08
215	19.60	19.95	20.40	20.86	21.33	21.80	22.28	22.77	23.27	24.30
220	19.99	20.33	20.77	21.22	21.67	22.13	22.59	23.06	23.54	24.53
225	20.37	20.71	21.14	21.57	22.01	22.45	22.90	23.36	23.82	24.76
230	20.75	21.08	21.50	21.92	22.34	22.77	23.21	23.65	24.10	25.01
235	21.13	21.45	21.86	22.27	22.68	23.10	23.52	23.95	24.38	25.26
240	21.51	21.82	22.22	22.61	23.02	23.42	23.83	24.25	24.67	25.52
245	21.88	22.19	22.57	22.96	23.35	23.75	24.15	24.55	24.96	25.78
250	22.25	22.55	22.92	23.30	23.68	24.07	24.46	24.85	25.24	26.04
255	22.61	22.91	23.27	23.64	24.02	24.39	24.77	25.15	25.54	26.31
260	22.98	23.26	23.62	23.98	24.35	24.71	25.08	25.45	25.83	26.58
265	23.34	23.62	23.97	24.32	24.68	25.03	25.39	25.76	26.12	26.85
270	23.69	23.97	24.31	24.66	25.01	25.35	25.71	26.06	26.41	27.13
275	24.05	24.32	24.65	24.99	25.33	25.67	26.02	26.36	26.71	27.40
280	24.40	24.66	24.99	25.32	25.65	25.99	26.33	26.66	27.00	27.68
285	24.75	25.01	25.33	25.66	25.98	26.31	26.64	26.97	27.30	27.96
290	25.09	25.35	25.67	25.98	26.30	26.62	26.95	27.27	27.59	28.24
295	25.44	25.69	26.00	26.31	26.63	26.94	27.25	27.57	27.89	28.52
300	25.78	26.03	26.33	26.64	26.95	27.25	27.56	27.87	28.18	28.80
310	26.46	26.70	26.99	27.29	27.58	27.88	28.18	28.47	28.77	29.37
320	27.13	27.36	27.65	27.93	28.22	28.50	28.79	29.07	29.36	29.93
330	27.80	28.02	28.29	28.57	28.84	29.12	29.40	29.67	29.95	30.50
340	28.45	28.67	28.94	29.20	29.47	29.74	30.00	30.27	30.54	31.07

Table 22. (Cont.)

T,K	P, MPa 0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
350	29.11	29.31	29.57	29.83	30.09	30.35	30.61	30.87	31.12	31.64
360	29.75	29.96	30.21	30.46	30.71	30.96	31.21	31.46	31.71	32.21
370	30.40	30.59	30.84	31.08	31.33	31.57	31.81	32.06	32.30	32.78
380	31.03	31.23	31.46	31.70	31.94	32.18	32.41	32.65	32.88	33.35
390	31.67	31.85	32.09	32.32	32.55	32.78	33.01	33.24	33.47	33.92
400	32.30	32.48	32.71	32.93	33.16	33.38	33.61	33.83	34.05	34.50
410	32.93	33.10	33.32	33.54	33.76	33.98	34.20	34.42	34.64	35.07
420	33.55	33.72	33.94	34.15	34.37	34.58	34.79	35.01	35.22	35.64
430	34.17	34.34	34.55	34.76	34.97	35.18	35.39	35.60	35.80	36.21
440	34.79	34.96	35.16	35.37	35.57	35.78	35.98	36.18	36.38	36.79
450	35.41	35.57	35.77	35.97	36.17	36.37	36.57	36.77	36.97	37.36
460	36.03	36.18	36.38	36.58	36.77	36.97	37.16	37.36	37.55	37.93
470	36.64	36.80	36.99	37.18	37.37	37.56	37.75	37.94	38.13	38.51
480	37.25	37.40	37.59	37.78	37.97	38.16	38.34	38.53	38.71	39.08
490	37.86	38.01	38.20	38.38	38.57	38.75	38.93	39.11	39.29	39.66
500	38.47	38.62	38.80	38.98	39.16	39.34	39.52	39.70	39.88	40.23

T,K	P, MPa 6.0	7.0	8.0	9.0	10.0	15.0	20.0	30.0	40.0	50.0
80	135.3	136.2	137.0	137.9	138.7					
85	128.5	129.5	130.5	131.5	132.4	136.9	141.0			
90	121.5	122.6	123.7	124.8	125.9	130.8	135.4			
95	114.2	115.5	116.7	117.9	119.1	124.6	129.5	138.3		
100	106.8	108.2	109.6	111.0	112.3	118.3	123.6	133.0	141.2	
105	99.29	100.9	102.5	104.0	105.4	112.0	117.7	127.7	136.3	144.0
110	91.66	93.53	95.31	96.99	98.60	105.7	111.9	122.4	131.4	139.4
115	83.93	86.09	88.10	90.00	91.79	99.62	106.2	117.2	126.6	134.8
120	76.20	78.68	80.96	83.08	85.07	93.59	100.6	112.2	121.8	130.3
125	68.83	71.58	74.08	76.40	78.56	87.75	95.19	107.2	117.2	125.9
130	62.09	65.11	67.78	70.21	72.49	82.16	89.97	102.5	112.8	121.7
135	54.60	58.90	62.00	64.62	66.99	76.92	85.01	97.99	108.5	117.6
140	44.68	51.47	55.91	59.16	61.83	72.10	80.35	93.65	104.4	113.6
145	36.79	43.55	49.03	53.22	56.51	67.64	76.01	89.53	100.4	109.8
150	31.88	37.43	42.63	47.16	50.95	63.39	71.97	85.65	96.72	106.2
155	28.93	33.29	37.72	41.93	45.75	59.24	68.17	82.00	93.17	102.7
160	27.14	30.60	34.25	37.93	41.45	55.25	64.58	78.58	89.82	99.44
165	26.06	28.87	31.90	35.04	38.17	51.57	61.18	75.37	86.65	96.31
170	25.41	27.77	30.32	33.01	35.75	48.36	58.04	72.38	83.68	93.34
175	25.04	27.07	29.27	31.60	34.01	45.67	55.20	69.58	80.88	90.54
180	24.84	26.65	28.58	30.63	32.76	43.46	52.69	67.00	78.26	87.89
185	24.76	26.39	28.13	29.96	31.86	41.67	50.51	64.62	75.82	85.40
190	24.76	26.26	27.84	29.49	31.22	40.22	48.63	62.44	73.54	83.05
195	24.82	26.20	27.66	29.18	30.75	39.05	47.01	60.46	71.42	80.85
200	24.91	26.21	27.56	28.96	30.42	38.09	45.62	58.67	69.45	78.78

Table 22. (Ccnt.)

	P, MPa								
T,K	6.0	7.0	8.0	9.0	10.0	20.0	30.0	50.0	75.0	100.0
200	24.91	26.21	27.56	28.96	30.42	45.62	58.67			
205	25.04	26.25	27.52	28.83	30.18	44.43	57.04			
210	25.19	26.34	27.53	28.75	30.02	43.41	55.57			
215	25.35	26.45	27.57	28.73	29.92	42.53	54.25	73.34		
220	25.54	26.58	27.65	28.74	29.86	41.78	53.05	71.76		
225	25.73	26.73	27.75	28.79	29.85	41.13	51.98	70.28		
230	25.94	26.89	27.87	28.86	29.87	40.59	51.02	68.91		
235	26.16	27.07	28.01	28.96	29.92	40.12	50.15	67.62		
240	26.38	27.27	28.16	29.07	30.00	39.73	49.38	66.43		
245	26.62	27.47	28.33	29.20	30.09	39.40	48.69	65.32		
250	26.85	27.67	28.51	29.35	30.21	39.12	48.07	64.29		
255	27.10	27.89	28.70	29.51	30.33	38.90	47.52	63.33		
260	27.34	28.11	28.89	29.68	30.47	38.72	47.04	62.44		
265	27.59	28.34	29.10	29.86	30.63	38.57	46.60	61.62	78.14	
270	27.85	28.57	29.31	30.05	30.79	38.46	46.22	60.85	77.09	
275	28.11	28.81	29.52	30.24	30.95	38.38	45.89	60.15	76.11	
280	28.37	29.05	29.75	30.44	31.14	38.32	45.59	59.49	75.18	
285	28.63	29.30	29.97	30.65	31.33	38.29	45.34	58.89	74.29	
290	28.89	29.55	30.20	30.86	31.53	38.28	45.12	58.33	73.46	
295	29.16	29.80	30.44	31.08	31.73	38.29	44.93	57.82	72.68	
300	29.42	30.05	30.68	31.30	31.93	38.32	44.77	57.34	71.94	
310	29.96	30.56	31.16	31.76	32.36	38.42	44.52	56.51	70.58	
320	30.51	31.08	31.65	32.23	32.80	38.57	44.37	55.80	69.38	82.08
330	31.05	31.60	32.15	32.71	33.26	38.77	44.29	55.22	68.31	80.66
340	31.60	32.13	32.66	33.19	33.72	39.00	44.28	54.74	67.37	79.38
350	32.15	32.67	33.18	33.69	34.20	39.27	44.32	54.35	66.55	78.21
360	32.71	33.20	33.70	34.19	34.68	39.57	44.41	54.04	65.82	77.16
370	33.26	33.74	34.22	34.70	35.18	39.88	44.54	53.81	65.19	76.22
380	33.82	34.29	34.75	35.21	35.67	40.22	44.71	53.64	64.65	75.37
390	34.38	34.83	35.28	35.73	36.18	40.58	44.91	53.52	64.18	74.60
400	34.94	35.38	35.82	36.25	36.69	40.96	45.14	53.46	63.78	73.92
410	35.50	35.93	36.35	36.78	37.20	41.34	45.40	53.44	63.45	73.32
420	36.06	36.48	36.89	37.31	37.72	41.74	45.68	53.47	63.17	72.78
430	36.62	37.03	37.43	37.84	38.24	42.16	45.98	53.53	62.95	72.31
440	37.19	37.58	37.98	38.37	38.76	42.58	46.30	53.63	62.78	71.89
450	37.75	38.14	38.52	38.91	39.29	43.01	46.63	53.76	62.65	71.54
460	38.31	38.69	39.07	39.45	39.82	43.46	46.98	53.91	62.57	71.23
470	38.88	39.25	39.62	39.99	40.35	43.90	47.34	54.09	62.52	70.97
480	39.45	39.81	40.17	40.53	40.89	44.36	47.72	54.30	62.51	70.75
490	40.01	40.37	40.72	41.08	41.42	44.82	48.10	54.53	62.53	70.58
500	40.58	40.93	41.28	41.62	41.95	45.29	48.50	54.77	62.59	70.45

Table 23. Viscosity of Oxygen

T,K	P, MPa 0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
75	2869.	2879.	2892.	2904.	2917.	2930.	2942.	2955.	2968.
80	2517.	2526.	2538.	2549.	2561.	2572.	2584.	2595.	2607.
85	2215.	2224.	2234.	2245.	2255.	2266.	2276.	2287.	2297.
90	1956.	1963.	1973.	1983.	1993.	2003.	2012.	2022.	2032.
95	70.7	1740.	1749.	1758.	1767.	1777.	1786.	1795.	1804.
100	74.6	1546.	1555.	1564.	1572.	1581.	1590.	1599.	1607.
105	78.4	1377.	1386.	1394.	1403.	1411.	1420.	1428.	1436.
110	82.3	83.8	1237.	1245.	1254.	1262.	1270.	1279.	1287.
115	86.1	87.5	1104.	1112.	1121.	1129.	1138.	1146.	1154.
120	89.9	91.3	93.5	993.2	1002.	1010.	1019.	1027.	1036.
125	93.7	95.0	97.1	883.0	892.5	901.8	911.0	919.9	928.7
130	97.4	98.6	100.7	103.4	789.6	799.9	810.0	819.8	829.3
135	101.1	102.3	104.2	106.7	110.2	701.3	713.2	724.4	735.2
140	104.8	105.9	107.7	110.1	113.1	117.5	615.3	629.6	642.9
145	108.4	109.5	111.3	113.4	116.2	119.9	125.1	525.7	545.4
150	112.1	113.1	114.8	116.8	119.3	122.6	126.8	132.8	143.1
155	115.6	116.7	118.2	120.2	122.5	125.4	129.1	133.8	140.5
160	119.2	120.2	121.7	123.5	125.7	128.4	131.6	135.6	140.8
165	122.7	123.7	125.1	126.8	128.9	131.4	134.3	137.8	142.2
170	126.2	127.1	128.5	130.1	132.1	134.4	137.1	140.3	144.0
175	129.7	130.5	131.9	133.4	135.3	137.4	139.9	142.8	146.2
180	133.1	133.9	135.2	136.7	138.5	140.5	142.8	145.5	148.5
185	136.5	137.3	138.5	139.9	141.6	143.5	145.7	148.2	151.0
190	139.8	140.6	141.8	143.2	144.8	146.6	148.6	150.9	153.5
195	143.1	143.9	145.0	146.4	147.9	149.6	151.6	153.7	156.2
200	146.4	147.2	148.3	149.5	151.0	152.6	154.5	156.5	158.8
205	149.7	150.4	151.5	152.7	154.1	155.7	157.4	159.4	161.5
210	152.9	153.6	154.6	155.8	157.2	158.7	160.3	162.2	164.2
215	156.1	156.8	157.8	158.9	160.2	161.6	163.2	165.0	166.9
220	159.3	159.9	160.9	162.0	163.2	164.6	166.1	167.8	169.7
225	162.4	163.0	164.0	165.0	166.2	167.6	169.0	170.6	172.4
230	165.5	166.1	167.0	168.1	169.2	170.5	171.9	173.4	175.1
235	168.6	169.2	170.1	171.1	172.2	173.4	174.8	176.2	177.8
240	171.6	172.2	173.1	174.0	175.1	176.3	177.6	179.0	180.6
245	174.7	175.2	176.1	177.0	178.0	179.2	180.4	181.8	183.3
250	177.7	178.2	179.0	179.9	180.9	182.0	183.3	184.6	186.0
255	180.6	181.2	181.9	182.8	183.8	184.9	186.1	187.3	188.7
260	183.6	184.1	184.9	185.7	186.7	187.7	188.8	190.1	191.4
265	186.5	187.0	187.7	188.6	189.5	190.5	191.6	192.8	194.1
270	189.4	189.9	190.6	191.4	192.3	193.3	194.4	195.5	196.7
275	192.3	192.7	193.4	194.2	195.1	196.1	197.1	198.2	199.4
280	195.1	195.6	196.3	197.0	197.9	198.8	199.8	200.9	202.0
285	197.9	198.4	199.1	199.8	200.6	201.5	202.5	203.5	204.6
290	200.7	201.2	201.8	202.6	203.4	204.2	205.2	206.2	207.3
295	203.5	204.0	204.6	205.3	206.1	206.9	207.8	208.8	209.9
300	206.3	206.7	207.3	208.0	208.8	209.6	210.5	211.4	212.5

Table 23. (Cont.)

	P, MPa								
T,K	5.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	35.0
80	2630.	2652.	2698.	2744.	2857.				
85	2318.	2339.	2381.	2422.	2525.	2627.	2729.	2830.	
90	2051.	2071.	2109.	2147.	2241.	2335.	2427.	2519.	2610.
95	1822.	1840.	1876.	1911.	1999.	2085.	2169.	2253.	2336.
100	1624.	1642.	1675.	1709.	1791.	1870.	1949.	2026.	2102.
105	1453.	1469.	1502.	1534.	1611.	1686.	1759.	1831.	1901.
110	1303.	1319.	1350.	1381.	1455.	1526.	1595.	1662.	1728.
115	1170.	1186.	1217.	1247.	1319.	1388.	1453.	1517.	1578.
120	1052.	1068.	1099.	1129.	1200.	1256.	1329.	1389.	1448.
125	945.8	962.3	994.0	1024.	1094.	1159.	1220.	1278.	1334.
130	847.6	865.2	898.2	929.2	999.9	1064.	1123.	1180.	1233.
135	755.7	774.9	810.3	842.7	915.1	979.2	1038.	1092.	1145.
140	667.2	689.2	728.4	763.2	838.2	902.9	961.3	1015.	1066.
145	578.0	605.3	650.7	689.0	768.1	834.1	892.4	945.8	995.5
150	478.5	518.3	575.2	618.9	703.7	771.5	830.2	883.2	932.2
155	179.0	414.8	499.1	551.5	644.2	714.4	773.9	826.8	875.2
160	158.1	227.6	417.8	485.6	589.0	662.2	722.6	775.6	823.6
165	154.7	179.0	326.5	420.1	537.6	614.4	675.9	729.1	776.9
170	154.2	170.2	250.8	356.1	489.9	570.5	633.3	686.8	734.4
175	154.8	167.2	215.6	300.8	445.8	530.3	594.4	648.2	695.7
180	156.1	166.4	200.7	262.1	405.9	493.6	558.9	613.1	660.4
185	157.8	166.6	193.6	238.7	370.7	460.4	526.6	581.0	628.3
190	159.7	167.6	189.9	224.9	341.0	430.6	497.3	551.8	598.9
195	161.9	168.9	188.2	216.6	316.8	414.2	470.8	525.2	572.1
200	164.1	170.5	187.5	211.5	297.8	381.1	447.1	501.1	547.6
205	166.4	172.3	187.6	208.4	283.1	361.3	425.8	479.3	525.3
210	168.8	174.3	188.2	206.6	271.9	344.5	407.0	459.6	505.1
215	171.3	176.4	189.1	205.7	263.5	330.3	390.4	441.9	486.6
220	173.8	178.6	190.4	205.4	257.1	318.5	375.9	426.0	469.9
225	176.3	180.8	191.8	205.6	252.3	308.7	363.2	411.8	454.8
230	178.6	183.1	193.4	206.2	248.8	300.7	352.3	399.1	441.1
235	181.4	185.4	195.1	207.0	246.1	294.1	342.8	387.9	428.7
240	184.0	187.8	197.0	208.1	244.2	288.7	334.6	378.0	417.6
245	186.5	190.2	198.9	209.3	243.0	284.3	327.6	369.2	407.6
250	189.1	192.6	200.9	210.7	242.1	280.7	321.6	361.4	398.6
255	191.7	195.0	202.9	212.2	241.7	277.8	316.5	354.6	390.5
260	194.3	197.5	205.0	213.8	241.6	275.6	312.2	348.6	383.3
265	196.8	199.9	207.1	215.5	241.8	273.8	308.5	343.3	376.8
270	199.4	202.4	209.2	217.3	242.2	272.4	305.4	338.8	371.0
275	202.0	204.8	211.4	219.1	242.8	271.5	302.8	334.7	365.9
280	204.5	207.3	213.6	221.0	243.6	270.8	300.7	331.3	361.3
285	207.1	209.7	215.8	222.9	244.5	270.4	298.9	328.3	357.2
290	209.6	212.2	218.1	224.9	245.5	270.3	297.5	325.7	353.6
295	212.1	214.6	220.3	226.9	246.6	270.3	296.4	323.4	350.4
300	214.7	217.1	222.6	228.9	247.9	270.5	295.5	321.6	347.6

Table 24. Thermal Conductivity of Oxygen, $mWK^{-1}m^{-1}$

	P, MPa								
T,K	0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
75	172.6	172.7	172.9	173.0	173.1	173.2	173.3	173.4	173.6
80	166.1	166.2	166.3	166.5	166.6	166.7	166.9	167.0	167.1
85	159.2	159.3	159.4	159.6	159.7	159.9	160.0	160.1	160.3
90	152.0	152.1	152.3	152.5	152.6	152.8	152.9	153.1	153.2
95	8.87	144.9	145.1	145.3	145.4	145.6	145.8	146.0	146.1
100	9.31	137.7	137.9	138.1	138.3	138.5	138.7	138.8	139.0
105	9.77	130.5	130.8	131.0	131.2	131.4	131.6	131.8	132.0
110	10.24	11.56	123.7	124.0	124.2	124.5	124.7	124.9	125.2
115	10.72	11.90	116.8	117.1	117.4	117.6	117.9	118.2	118.4
120	11.20	12.26	13.88	110.3	110.6	110.9	111.2	111.5	111.8
125	11.68	12.64	14.08	103.5	103.9	104.3	104.6	105.0	105.3
130	12.15	13.04	14.32	15.92	97.07	97.56	98.02	98.47	98.90
135	12.63	13.44	14.60	16.00	17.33	90.59	91.20	91.78	92.32
140	13.10	13.85	14.90	16.15	17.69	19.81	84.01	84.81	85.54
145	13.57	14.27	15.23	16.35	17.69	19.40	21.85	77.46	78.49
150	14.04	14.68	15.57	16.58	17.77	19.21	21.10	23.83	28.90
155	14.50	15.10	15.92	16.84	17.90	19.16	20.70	22.72	25.61
160	14.95	15.51	16.28	17.12	18.08	19.19	20.50	22.11	24.20
165	15.41	15.93	16.64	17.42	18.29	19.28	20.42	21.76	23.40
170	15.85	16.34	17.01	17.73	18.53	19.41	20.42	21.57	22.92
175	16.29	16.76	17.38	18.05	18.78	19.59	20.48	21.49	22.64
180	16.73	17.17	17.75	18.38	19.05	19.79	20.60	21.49	22.48
185	17.16	17.58	18.12	18.71	19.34	20.02	20.75	21.55	22.43
190	17.59	17.98	18.50	19.05	19.64	20.26	20.94	21.66	22.44
195	18.01	18.39	18.88	19.39	19.94	20.53	21.15	21.81	22.52
200	18.43	18.79	19.25	19.74	20.26	20.81	21.38	21.99	22.64
205	18.85	19.19	19.63	20.10	20.58	21.10	21.64	22.20	22.80
210	19.26	19.59	20.01	20.45	20.91	21.40	21.90	22.43	22.99
215	19.67	19.98	20.39	20.81	21.25	21.70	22.18	22.68	23.20
220	20.08	20.38	20.76	21.16	21.58	22.02	22.47	22.94	23.43
225	20.48	20.77	21.14	21.52	21.92	22.34	22.77	23.21	23.68
230	20.88	21.16	21.51	21.88	22.27	22.66	23.07	23.50	23.93
235	21.28	21.55	21.89	22.24	22.61	22.99	23.38	23.79	24.20
240	21.67	21.93	22.26	22.61	22.96	23.32	23.70	24.08	24.48
245	22.07	22.32	22.64	22.97	23.31	23.66	24.02	24.39	24.77
250	22.46	22.70	23.01	23.33	23.66	24.00	24.34	24.70	25.06
255	22.85	23.08	23.38	23.69	24.01	24.33	24.67	25.01	25.36
260	23.24	23.46	23.76	24.05	24.36	24.68	25.00	25.33	25.66
265	23.62	23.84	24.13	24.42	24.71	25.02	25.33	25.65	25.97
270	24.01	24.22	24.50	24.78	25.07	25.36	25.66	25.97	26.29
275	24.39	24.60	24.87	25.14	25.42	25.71	26.00	26.30	26.60
280	24.77	24.98	25.24	25.50	25.78	26.06	26.34	26.63	26.92
285	25.15	25.35	25.61	25.87	26.13	26.40	26.68	26.96	27.25
290	25.53	25.73	25.98	26.23	26.49	26.75	27.02	27.29	27.57
295	25.91	26.10	26.34	26.59	26.85	27.10	27.36	27.63	27.90
300	26.29	26.47	26.71	26.96	27.20	27.45	27.71	27.97	28.23

Table 24. (Cont.)

T,K	P, MPa 5.0	6.0	8.0	10.0	15.0	20.0	25.0	30.0	35.0
80	167.4	167.6	168.1	168.6	169.8				
85	160.6	160.8	161.4	161.9	163.2	164.4	165.5	166.6	
90	153.5	153.8	154.4	155.0	156.4	157.7	158.9	160.1	161.2
95	146.5	146.8	147.4	148.0	149.5	150.9	152.2	153.5	154.7
100	139.4	139.7	140.4	141.1	142.7	144.2	145.6	146.9	148.2
105	132.4	132.8	133.6	134.3	136.0	137.6	139.1	140.5	141.8
110	125.6	126.0	126.9	127.7	129.6	131.3	132.9	134.3	135.7
115	118.9	119.4	120.4	121.3	123.3	125.1	126.8	128.4	129.8
120	112.4	113.0	114.0	115.0	117.3	119.2	121.0	122.7	124.2
125	106.0	106.7	107.9	109.0	111.4	113.6	115.5	117.2	118.8
130	99.71	100.4	101.8	103.1	105.8	108.2	110.2	112.1	113.7
135	93.34	94.27	95.94	97.41	100.5	103.0	105.2	107.2	108.9
140	86.86	88.03	90.06	91.79	95.31	98.12	100.4	102.5	104.4
145	80.25	81.75	84.23	86.27	90.29	93.39	95.95	98.16	100.1
150	73.64	75.57	78.56	80.92	85.45	88.87	91.64	93.99	96.06
155	45.19	69.34	73.22	75.89	80.85	84.56	87.54	90.05	92.22
160	31.36	53.59	67.81	71.22	76.57	80.50	83.66	86.31	88.60
165	28.15	36.85	60.12	66.40	72.63	76.71	80.02	82.80	85.19
170	26.49	31.90	49.49	60.44	68.90	73.21	76.62	79.50	81.98
175	25.49	29.41	41.43	53.35	65.12	69.94	73.46	76.42	78.98
180	24.86	27.91	36.58	46.82	61.07	66.76	70.51	73.55	76.17
185	24.46	26.94	33.59	41.82	56.85	63.59	67.68	70.85	73.54
190	24.22	26.31	31.64	38.26	52.75	60.39	64.94	68.30	71.08
195	24.09	25.90	30.34	35.75	49.05	57.27	62.27	65.86	68.76
200	24.06	25.65	29.45	33.99	45.92	54.33	59.70	63.53	66.56
205	24.09	25.52	28.84	32.75	43.37	51.67	57.28	61.32	64.49
210	24.18	25.48	28.44	31.86	41.32	49.33	55.05	59.24	62.53
215	24.30	25.50	28.18	31.22	39.71	47.32	53.03	57.33	60.71
220	24.46	25.57	28.02	30.78	38.44	45.62	51.25	55.58	59.03
225	24.65	25.68	27.95	30.47	37.45	44.18	49.67	54.00	57.48
230	24.85	25.82	27.94	30.26	36.67	42.97	48.30	52.58	56.07
235	25.07	25.99	27.97	30.13	36.05	41.96	47.10	51.31	54.79
240	25.31	26.18	28.04	30.06	35.57	41.12	46.05	50.19	53.63
245	25.56	26.38	28.15	30.05	35.19	40.42	45.15	49.18	52.59
250	25.81	26.60	28.28	30.07	34.91	39.83	44.36	48.29	51.65
255	26.08	26.84	28.43	30.13	34.69	39.35	43.69	47.51	50.81
260	26.36	27.08	28.60	30.22	34.54	38.95	43.11	46.81	50.05
265	26.64	27.33	28.79	30.33	34.43	38.63	42.62	46.21	49.37
270	26.93	27.60	29.00	30.47	34.38	38.38	42.20	45.68	48.78
275	27.23	27.87	29.21	30.62	34.36	38.18	41.85	45.22	48.25
280	27.53	28.15	29.44	30.80	34.37	38.03	41.56	44.33	47.78
285	27.83	28.43	29.68	30.99	34.42	37.92	41.32	44.49	47.38
290	28.14	28.72	29.93	31.19	34.49	37.86	41.14	44.21	47.02
295	28.45	29.02	30.19	31.40	34.58	37.83	40.99	43.97	46.72
300	28.77	29.32	30.45	31.63	34.70	37.83	40.89	43.78	46.46