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

H. J. M. HANLEY AND G. E. CHILDS

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

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THE VISCOSITY AND THERMAL CONDUCTIVITY COEFFICIENTS OF DILUTE NEON, KRYPTON, AND XENON

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THE VISCOSITY AND THERMAL CONDUCTIVITY COEFFICIENTS OF DILUTE NEON, KRYPTON, AND XENON

H. J. M. Hanley and G. E. Childs

The coefficients of viscosity and thermal conductivity for dilute neon, krypton, and xenon were examined by a method already proved successful for dilute argon, oxygen, and nitrogen. This method selects a suitable potential function, and its parameters, which is then used to correlate theory with experimental data, given the kinetic theory expressions for the transport coefficients. The method has recently been expanded and generalized and the results of this general study are applied in this note. The potential functions examined were members of the m-6, Kihara, Exp: 6, and Morse families. It was found that the Kihara was most suitable for neon, and the m-6, with m = 17 and m = 24, was most suitable for krypton and xenon, respectively. Viscosity and thermal conductivities were calculated from these functions and tables are given between 100 and 1000°K.

Key Words: dilute gases, neon, krypton, xenon, transport coefficients, correlations, m-6, Kihara, Exp: 6, Morse, potential functions.

1. INTRODUCTION

In this note we correlate transport coefficients of dilute neon, krypton, and xenon by applying a method which has been discussed and shown to be successful in previous publications for argon [1, 2] † and for oxygen and nitrogen [3] . Experimental transport coefficients for these gases were correlated by means of the rigorous kinetic theory expressions and a suitable intermolecular potential function. Recently this method has been considerably expanded and can now be generalized for any given potential function and for any property [4] , provided that theoretical tables for the potential and the property can be calculated.

† Numbers in brackets refer to references.

(Specifically, the properties second virial coefficient, Joule-Thomson coefficient, viscosity and diffusion coefficients; and the families m-6, Kihara, Exp: 6, and Morse were considered). The general study is not yet complete but three conclusions have resulted from it which are relevent to this note because they enable the correlation procedure to be considerably simplified. The conclusions are taken to be correct.

We first define a reduced temperature T^* by the relation $T^* = T/(\epsilon/k)$, where T is the absolute temperature, ϵ is the value of the maximum energy of attraction between two molecules for a given potential function, and k is Boltzmann's constant. We frequently refer to the temperature reduced with respect to the 12-6 (Lennard-Jones) potential, T^*_{12-6}; this choice is a matter of convenience because values of $(\epsilon/k)_{12-6}$ are known for most common substances, at least to a first approximation.

The conclusions from the general study can be stated:

1. It appears impossible to distinguish between one reasonable intermolecular potential function and another in the reduced temperature range of about $2.0 < T^*_{12-6} < 5.0$ ‡.

2. If a potential function of one family correlates data in a particular manner, it appears that a member of another family can always be chosen that will correlate the data in a similar manner. This is especially true for the temperature range $1.5 < T^*_{12-6} < 10.0$. This conclusion obviously includes the result of conclusion 1 above.

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‡ By "reasonable" we mean that the function is based on a model believed to approximate the real situation. The conclusions, therefore, may not be valid for such relatively simple models as the square well, triangular well, and so on.

3. It seems that it is impossible to find a three-parameter function that will satisfactorily correlate transport data over the temperature range of approximately $1.0 < T^*_{12-6} < 20.0$. This is a very wide range; for argon, for example, it is $125 < T°K < 2,500$.

> Also, preliminary calculations have indicated that the ability to distinguish between one function and another, which is already negligible between $2.0 < T^*_{12-6} < 5.0$, is further reduced over a wider temperature range if the data have a random error of about 0.5% or more.

It is not intended to discuss the general validity of these conclusions in this article, but we indicate the validity of 1 and 2 for transport processes by considering results from our previous investigations [1, 2, 3] . Consider first conclusion 2 for the special case of argon. Curve a, Fig. 1, shows the deviation curve obtained when the viscosity coefficient was correlated with the Kihara function [1] . We have now found that this deviation curve is essentially duplicated when a member of the m-6 family was used, m = 17 in this case (curve b). Undoubtedly a similar curve would have been obtained with a member of the Exp: 6 family. In other words, there most probably exists a value of α (the characteristic parameter of the Exp: 6 family) which will enable argon to be correlated in a similar manner; however, the necessary theoretical calculations for the Exp: 6 family are not yet complete.

With regard to conclusion 1 we can clearly demonstrate [Fig. 1 shown here; Fig. 2 of Ref. 1, and Figs. 5, 6, and 7 of Ref. 3] that in the range $2.0 < T^*_{12-6} < 5.0$, the m-6, Kihara, Exp: 6, and Morse functions all satisfactorily, and in like manner, correlate the data for argon, oxygen, and nitrogen.

The point we wish to emphasize is that in the range $1.5 < T^*_{12-6} < 10.0$, there is a lack of uniqueness in the choice of the three-parameter function investigated [4] . So before starting to investigate

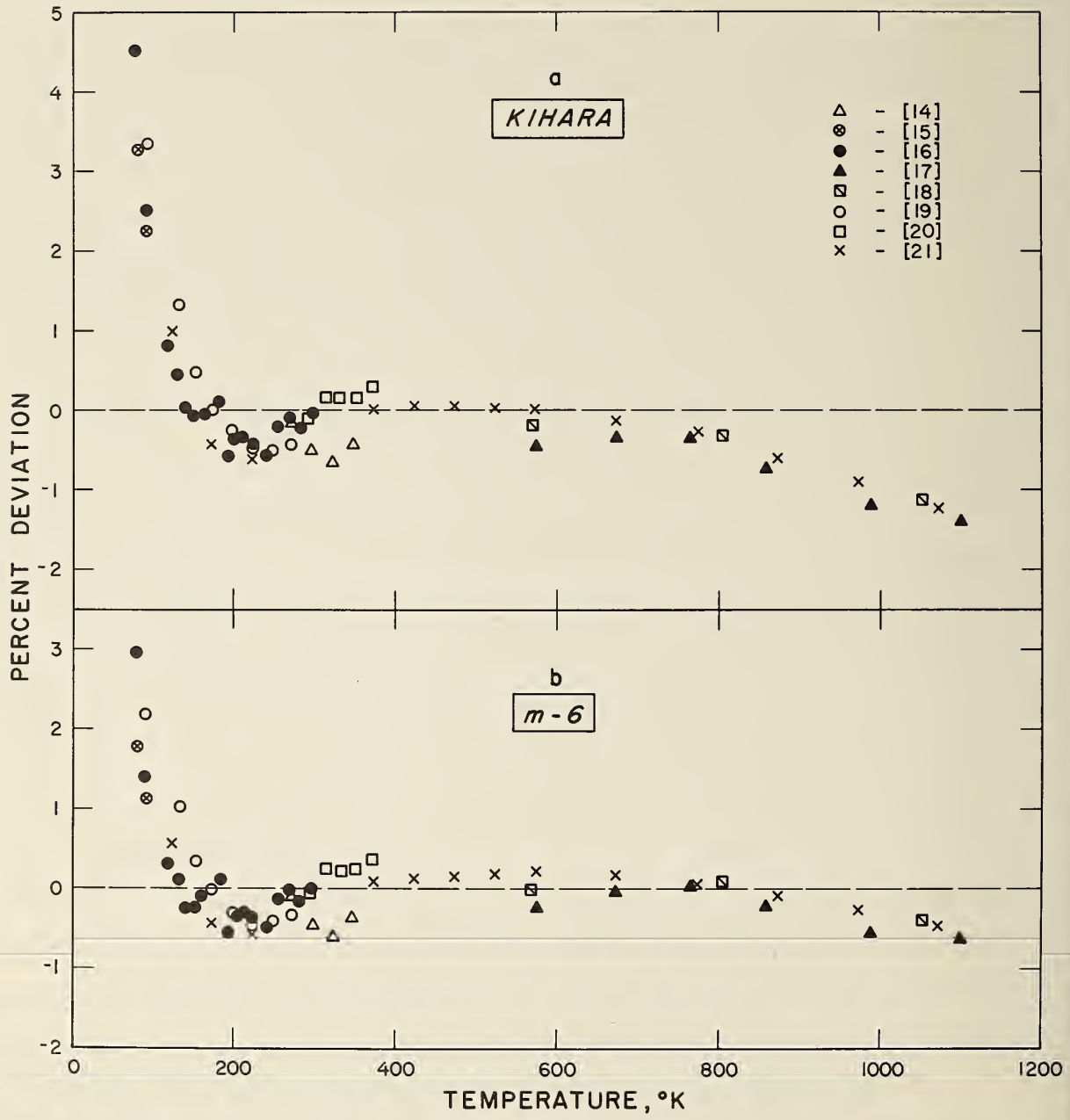

Fig. 1. Argon percent deviation curves $\left[\left(\frac{\eta_{exp} - \eta_{calc}}{\eta_{calc}}\right) \times 100\right]$. Curve a is reproduced from Fig. 2 of Ref. 2 and was calculated from the Kihara function with $\gamma = 0.1$, $\epsilon/k = 139.8°K$ and $\sigma = 3.35Å$. Curve b was calculated with the m-6 function, $m = 17$, $\epsilon/k = 151.5°K$ and $\sigma = 3.31Å$.

neon, krypton, or xenon, we can say that should we find that a particular potential function satisfactorily correlates the transport data in the temperature range $1.5 < T^*_{12-6} < 10.0$, we can be reasonably sure that this function is as suitable as any other function we might select. As mentioned above, this statement is based on studies of the m-6, Kihara, Exp: 6, and Morse functions—about all the common three-parameter functions in use at the present time.

The comment on the experimental requirements reinforces the decision made previously that it is best to study experimental viscosity data in order to determine a potential function and its parameters. Any attempt to select a potential function from experimental thermal conductivity data is not likely to be successful because thermal conductivity data are known to be less accurate.

2. THE POTENTIAL FUNCTIONS

The discussion in this note is restricted to the functions of four families: the m-6, the Kihara, the Exp: 6, and the Morse. The Kihara, in particular, has received much attention in the literature recently [5, 6, 7], as has the Morse function which has been described by several authors [8, 9]. The usage of the m-6 family is not as common as the others (although it contains the Lennard-Jones function) because of the difficulties in obtaining the tables of the collision integrals. Recently, however, these tables have become available [10].

If U(r) is the interaction potential of two molecules separated by a distance r, and ϵ is the maximum energy of attraction, or energy minimum, the potentials of the families are written:

m-6

$$U(r) = \epsilon \left[\left(\frac{\sigma}{r}\right)^m - \left(\frac{\sigma}{r}\right)^6 \right] \Big/ \left[\left(\frac{6}{m}\right)^{\frac{6}{m-6}} - \left(\frac{6}{m}\right)^{\frac{m}{m-6}} \right], \qquad (1)$$

where σ is the value of r at U(r) = 0.

Kihara

$$U(r) = 4\epsilon\left[\left(\frac{\sigma - a}{r - a}\right)^{12} - \left(\frac{\sigma - a}{r - a}\right)^{6}\right], \quad r > a \tag{2}$$

$$U(r) = \infty, \quad r \leq a;$$

here the finite size of the molecule is taken into consideration by including a core diameter, a. The reduced parameter γ, defined as a/σ, is the parameter characteristic of this family.

Exp: 6

$$U(r) = \frac{\epsilon}{1 - 6/\alpha}\left[\frac{6}{\alpha}\, e^{\alpha(1-r/r_m)} - (r_m/r)^6\right], \tag{3}$$

where r_m is the value of r at the energy minimum, and α the family parameter which represents the steepness of the repulsive part of the function.

Morse

$$U(r) = \epsilon\left\{\exp\left[-2\left(\frac{c}{\sigma}\right)\left(r - r_m\right)\right] - 2\exp\left[-\left(\frac{c}{\sigma}\right)\left(r - r_m\right)\right]\right\}, \tag{4}$$

where c is related to the curvature of the potential at $r = r_m$, and is the family parameter in this case.

3. KINETIC THEORY EXPRESSIONS FOR THE VISCOSITY AND THERMAL CONDUCTIVITY COEFFICIENTS

The kinetic theory for a dilute gas is formally complete[11, 12]; the Chapman-Enskog treatment of the Boltzmann equation gives the viscosity and thermal conductivity coefficients in terms of collision integrals which are functions of the gas dynamics and thus of the inter-

molecular potential. It is the lack of knowledge of the latter which restricts the applicability of the kinetic theory expressions. These expressions are:

Viscosity (η)

$$\eta\, 10^6 = \frac{26.693\,(MT)^{\frac{1}{2}}}{R^2\Omega^{(2,2)^*}(T^*)}\, f_\eta \qquad \text{g cm}^{-1}\ \text{sec}^{-1}, \tag{5}$$

Thermal Conductivity (λ)

$$\lambda\, 10^6 = \frac{832.24\,(T/M)^{\frac{1}{2}}}{R^2\Omega^{(2,2)^*}(T^*)}\, f_\lambda \qquad \text{J cm}^{-1}\ \text{sec}^{-1}\ \text{deg}^{-1}, \tag{6}$$

where: M = molecular weight. (M = 20.183 for neon, M = 83.80 for krypton, M = 131.30 for xenon.)

R = a distance parameter, i.e., $R \equiv \sigma$ for the m-6, Kihara and Morse; and $R \equiv r_m$ for the Exp: 6.

T = the absolute temperature, °K.

$\Omega^{(2,2)^*}(T^*)$ = the reduced collision integrals (reduced by dividing by the integrals for the rigid sphere case) at the reduced temperature T^*, where $T^* = T/(\epsilon/k)$ with k the Boltzmann constant.

The terms f_η and f_λ account for higher mathematical approximations to η and λ and are slowly varying functions of T^* which seldom differ from unity by more than about 0.5%. To be consistent with the accuracy of the experimental viscosity and thermal conductivity data especially at extreme temperatures, the terms can be omitted from Eqs (5) and (6) without significant error.

Appropriate tables of the collision integrals as a function of T^* for each of the families were taken from Refs. 7, 10, 12, and 13. The numerical values of the integrals depend on the method of integration

which varies from one procedure to another, but it was verified that the choice of any particular set of tables made no significant difference to the results presented here.

4. EXPERIMENTAL DATA FOR NEON, KRYPTON, AND XENON

The experimental data were taken from the following references:

Neon, viscosity, Refs. 16, 17, 20, 22-26;
temperature range 80 - 1100°K.

Krypton, viscosity, Refs. 22, 25, 27, 28;
temperature range 283 - 972°K.

Xenon, viscosity, Refs. 22, 25, 28-30;
temperature range 288 - 972°K.

Neon, thermal conductivity, Refs. 31-37;
temperature range 90 - 579°K.

Krypton, thermal conductivity, Refs. 32, 33, 38;
temperature range 171 - 579°K.

Xenon, thermal conductivity, Refs. 30, 32, 33, 38;
temperature range 155 - 579°K.

5. METHOD OF CALCULATION AND RESULTS

5.1 VISCOSITY

The method for selecting a function and its parameters which will suitably correlate experimental data in conjunction with Eq (5) has been explained in detail in Refs. 1, 2, and 3. We investigated a particular function by first observing the variation of ϵ/k with T at a fixed R, then observing any subsequent changes caused by varying R. To do this, experimental values of η and the corresponding temperatures for a given gas were substituted in Eq (5) together with a sensible value for R, hence obtaining $\Omega^{(2,2)*}$ as a function of T. An interpolation computer routine then generated T^* by inserting the calculated $\Omega^{(2,2)*}$ into a given set of $\Omega^{(2,2)*}$ (T^*) for the function. From T^* and the expression $\epsilon/k = T/T^*$, ϵ/k was then computed as a function of T. This procedure

was repeated for several values of R, varying R by about 10% overall. The same experimental data were used for all functions of the four families. The procedure was repeated for all the gases.

The best value of R was that value associated with the curve having the least variation of ϵ/k over the widest temperature range, allowing for the approximate 1% experimental and interpolation error. Values of ϵ/k were chosen to obtain agreement at 293°K for neon[20] and krypton[25] and 298°K for xenon[25]. We estimated ϵ/k to about 1% and R to about 0.2% for neon, but for krypton and xenon the estimation is about 2% and 1%, for ϵ/k and R, respectively. The higher possibility for error is due to the lack of data for these two gases. Table I gives the values of the Lennard-Jones parameters for each gas.

TABLE I

Best values of the Lennard-Jones parameters obtained for neon, krypton, and xenon

Gas	ϵ/k, °K	σ, Å
neon	47.0	2.72
krypton	182.8	3.62
xenon	249.5	3.96

We report that the variation of ϵ/k and R obtained here for neon, krypton, and xenon was essentially the same as that obtained in Refs. 1 and 3. We also report a marked lack of sensitivity in choosing a function in the temperature range $2.0 < T^*_{12-6} < 5.0$ for all gases which is as it should be in view of conclusion 1 in the introductory remarks.

5.1.1 NEON

The experimental data are in the range $80 < T\ °K < 1100$ which is equivalent to a reduced range of $1.7 < T^*_{12-6} < 23.4$. We repeat that a marked lack of sensitivity characterized the choice of a potential func-

tion in the range $2.3 < T^*_{12-6} < 5.0$, where all functions essentially behave similarly. However, the functions behaved differently and gave different results in the range $5.0 < T^*_{12-6} < 27.0$, but in view of conclusion 3 we did not expect to find a function that resulted in good agreement between experiment and theory over the entire temperature range. It was felt that the Kihara function with $\gamma = 0.1$ (Table II) was the best possible. The deviation curve is plotted in Fig. 2.

TABLE II

Best functions and the parameters for neon, krypton, and xenon

Gas	Function	ϵ/k, °K	σ, Å
neon	Kihara ($\gamma = 0.1$)	53.2	2.67
krypton	m-6 (m = 17)	226.0	3.50
xenon	m-6 (m = 24)	382.3	3.73

It is assumed that functions of the m-6, Exp: 6, and possibly the Morse families also exist that could be used to obtain a similar deviation curve. At present we do not have complete tables of collision integrals for the values of α(Exp: 6) or c (Morse) that can completely verify this point, but application of the 16-6 member of the m-6 family ($\epsilon/k = 68.4$°K, $\sigma = 2.60$ Å) gives a deviation curve which is practically identical with Fig. 2.

5.1.2 KRYPTON AND XENON

For these gases the experimental viscosity data lie between 280 and 975°K. In terms of reduced temperatures, therefore, the range for krypton is $1.5 < T^*_{12-6} < 5.3$, and for xenon $1.1 < T^*_{12-6} < 3.9$. It is at once clear that the problem is not so much the choice of a function which correlates the data, because we have an embarassment of choices, but rather to find a function that can predict data outside the present

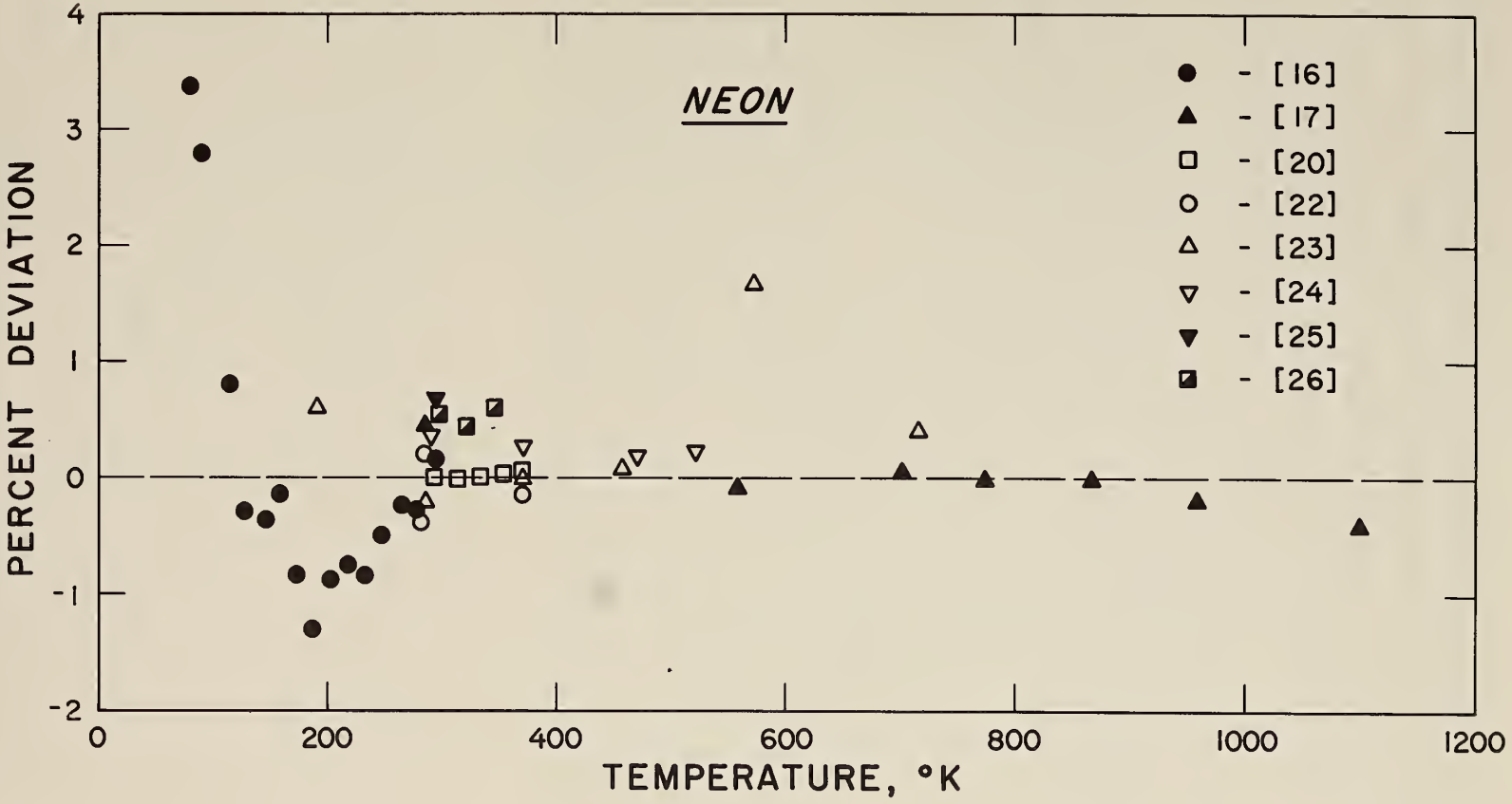

Fig. 2. Neon percent deviation curve $\left[\left(\frac{\eta_{exp} - \eta_{calc}}{\eta_{calc}}\right) \times 100\right]$ calculated from the Kihara potential function with $\gamma = 0.1$, $\epsilon/k = 53.2°K$ and $\sigma = 2.67Å$.

experimental range. The problem can be simplified because (conclusion 3) if a suitable function of a particular family can be found, then it is unlikely that the correlation can be satisfactorily improved upon considering another family from those for which collision integrals are available. Thus it is only really necessary to work with one family and the m-6 was selected for this purpose. We have shown that m = 16 is a suitable parameter for neon, and m = 17 for argon. If it is assumed that m increases with molecular weight, it can be expected that a value of at least m = 17 would be required for krypton and a higher value for xenon. From the collision integral tables available we selected m = 17 for krypton and m = 24 for xenon. Deviation curves are plotted in Fig. 3.

5.2 THERMAL CONDUCTIVITY

Thermal conductivities were calculated from Eq (6) using the functions and parameters determined from viscosity data as outlined above. Deviation curves are given in Figs. 4, 5, and 6 for neon, krypton, and xenon, respectively. It is well known that the scatter in experimental thermal conductivity coefficients between the results of different workers is large (about 5%) and the graphs indicate that the correlation is satisfactory.

6. CONCLUSION

The deviation curves verify that the kinetic theory expressions adequately correlate the experimental data available above 100°K, allowing for the estimated error in the data. The data for krypton and xenon are in a temperature range which does not allow us to choose a potential function that can be proved to be satisfactory over the complete temperature range considered, 100 to 1000°K. Although a sensible guess was made when selecting the function used for these latter gases, there must, of course, be some uncertainty in the theoretical transport coefficients calculated for temperatures outside the range of the data.

Tables of the viscosity and thermal conductivity in the temperature range 100 to 1000°K were computed for all gases, and they are given in Tables III, IV, and V for neon, krypton, and xenon, respectively. The viscosity tables are estimated to be accurate to 2% and the thermal conductivity tables accurate to 5%.

7. ACKNOWLEDGMENT

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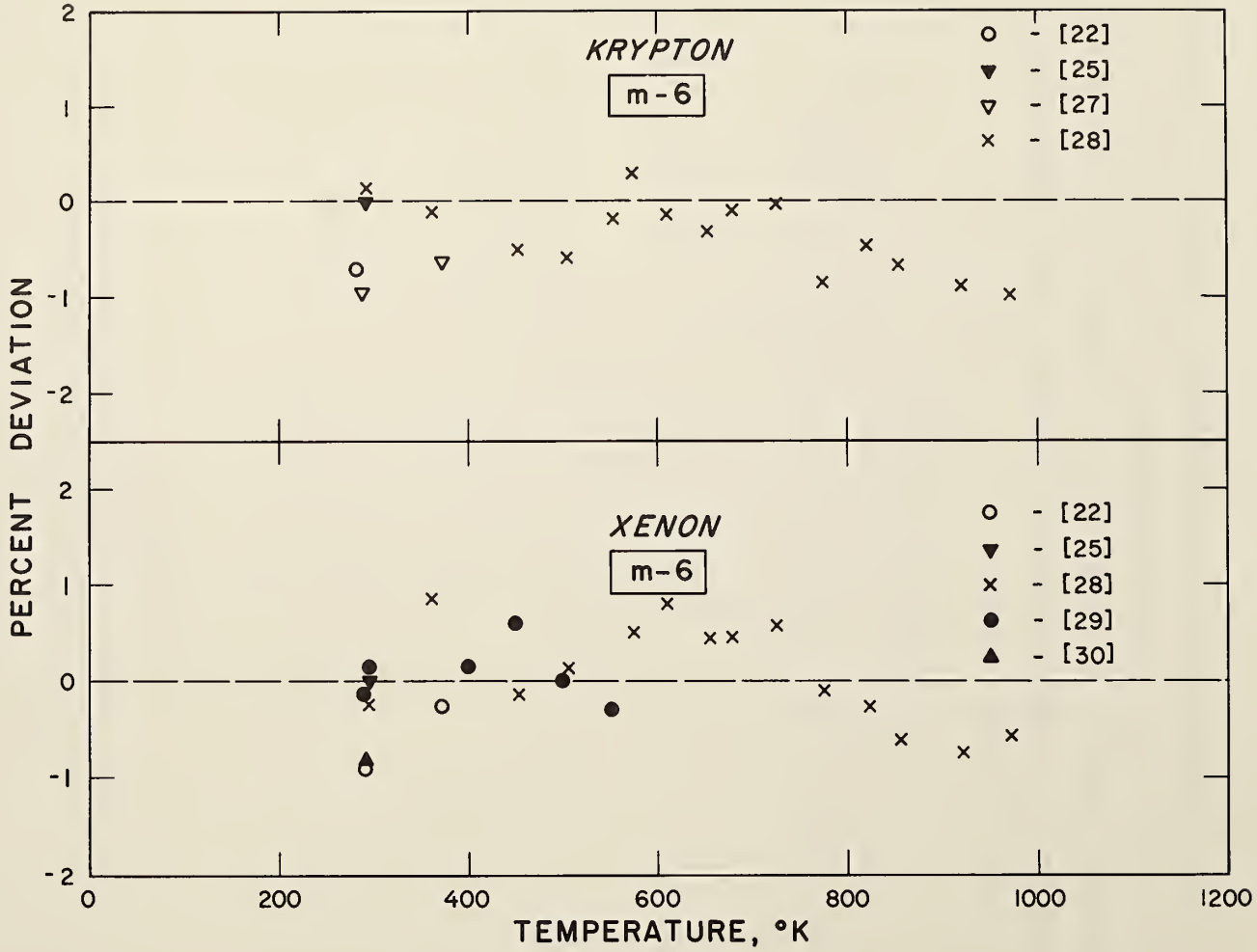

Fig. 3. Krypton and xenon percent deviation curves $\left[\left(\frac{\eta_{exp} - \eta_{calc}}{\eta_{calc}}\right) \times 100\right]$ calculated from the m-6 potential. For krypton, m = 17, ϵ/k = 226.0°K and σ = 3.50Å. For xenon, m = 24, ϵ/k = 382.3°K and σ = 3.73Å.

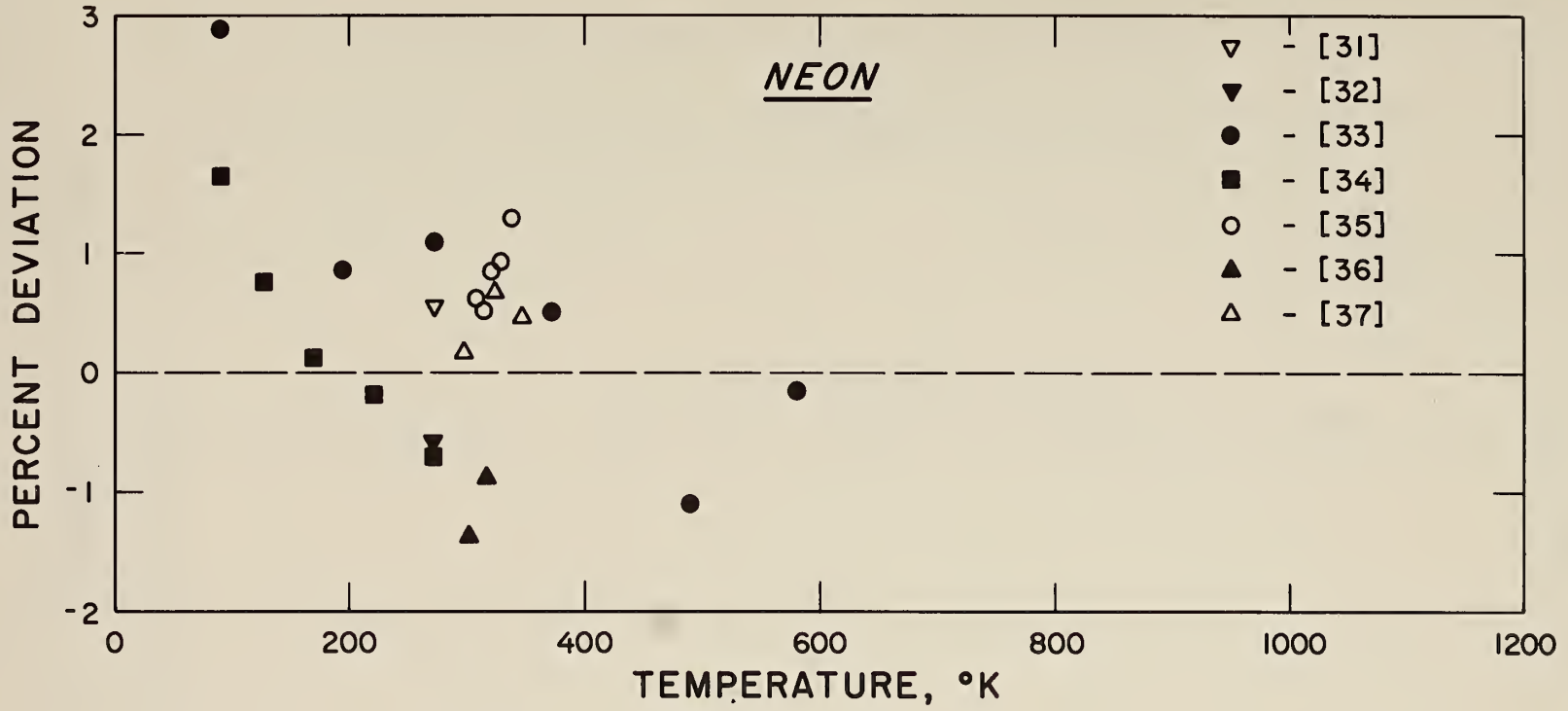

Fig. 4. Neon percent deviation curve $\left[\left(\frac{\lambda_{exp} - \lambda_{calc}}{\lambda_{calc}}\right) \times 100\right]$ calculated from the Kihara potential function, $\gamma = 0.1$, $\epsilon/k = 53.2°K$ and $\sigma = 2.67$ Å

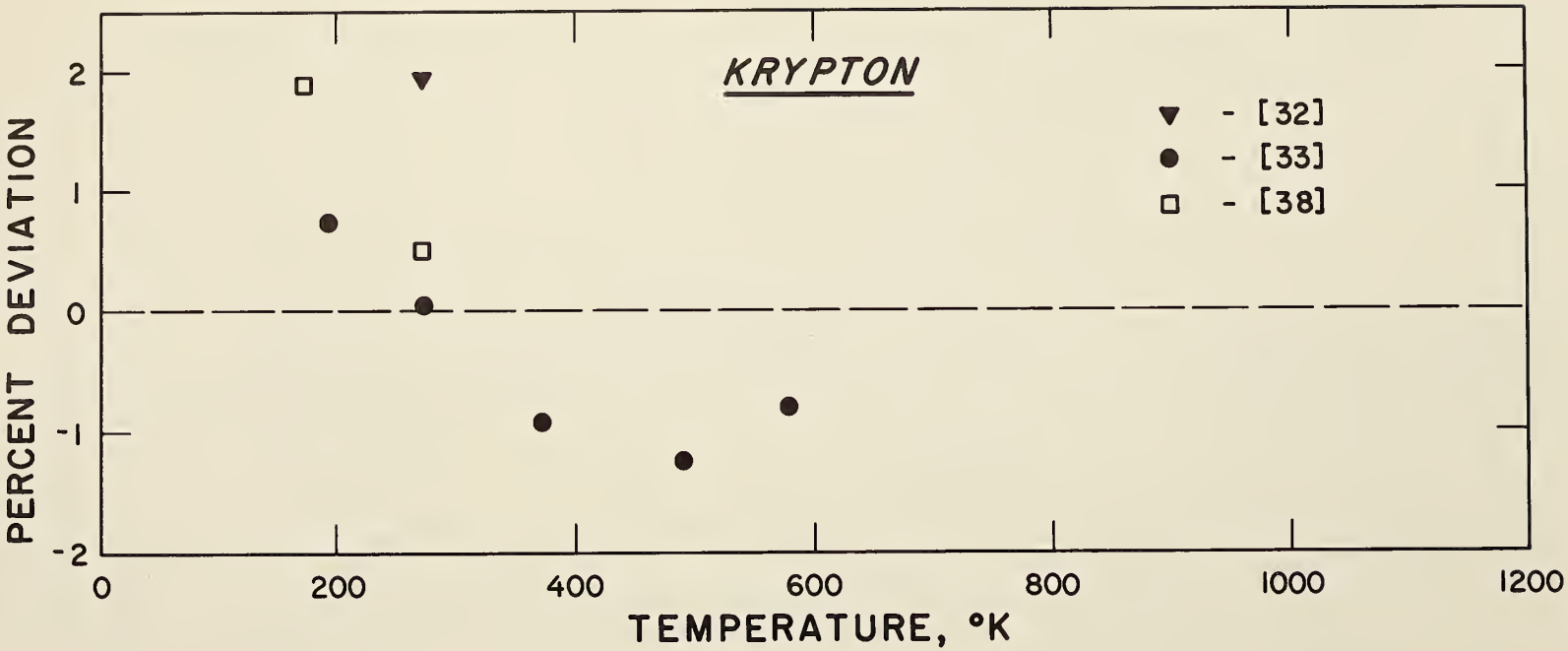

Fig. 5. Krypton percent deviation curve $\left[\left(\frac{\lambda_{exp} - \lambda_{calc}}{\lambda_{calc}}\right) \times 100\right]$ calculated from the m-6 potential function, m = 17, ϵ/k = 226.0°K and σ = 3.50 Å.

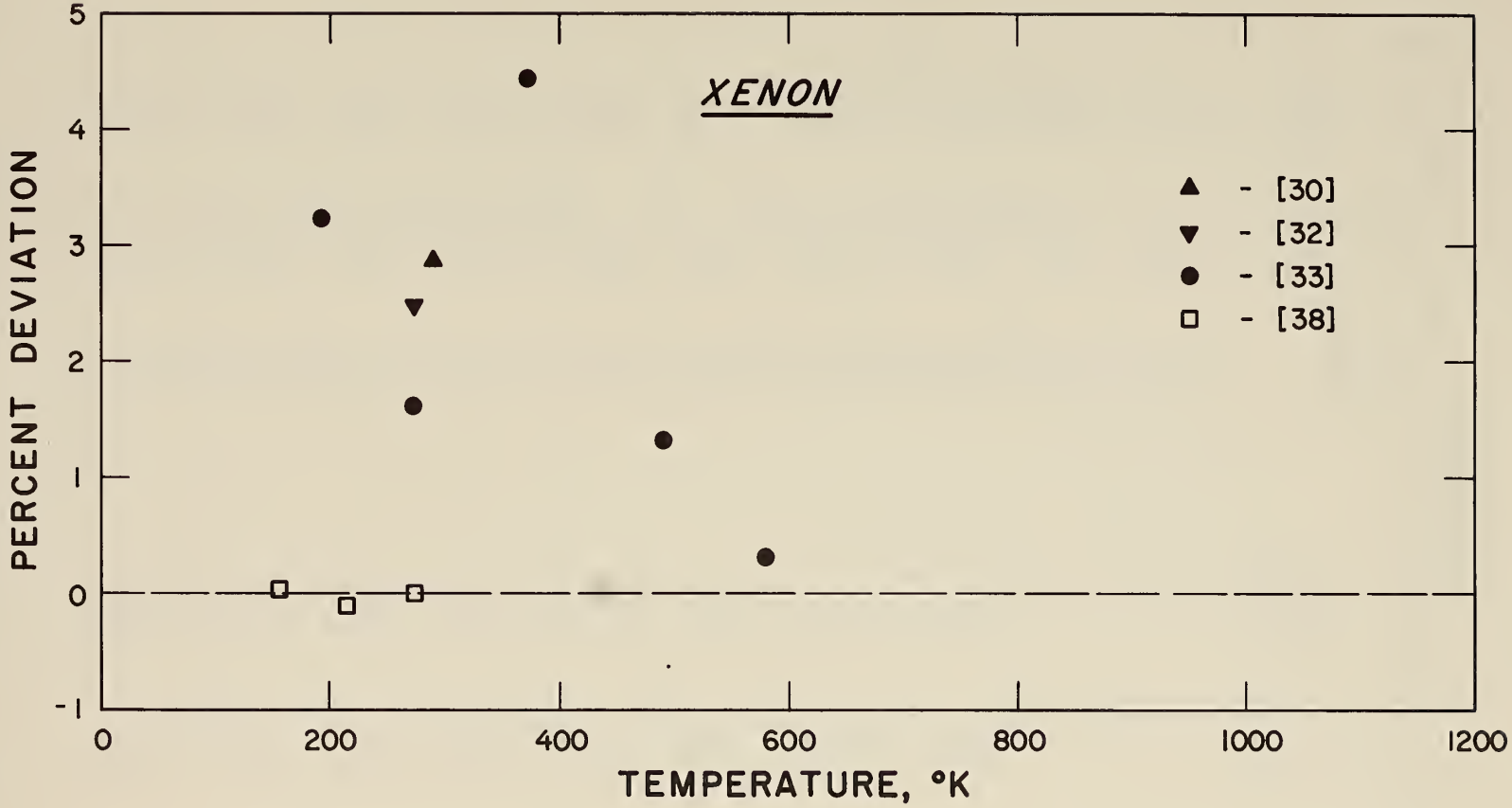

Fig. 6. Xenon percent deviation curve $\left[\left(\frac{\lambda_{exp} - \lambda_{calc}}{\lambda_{calc}}\right) \times 100\right]$ calculated from the m-6 potential function, m = 24, ϵ/k = 382.3°K and σ = 3.73Å.

TABLE III
VISCOSITY AND THERMAL CONDUCTIVITY OF GASEOUS NEON†

TEMPERATURE K	VISCOSITY G/CM-SEC $\eta 10^6$	THERMAL CONDUCTIVITY J/CM-SEC-DEG $\lambda 10^6$	TEMPERATURE K	VISCOSITY G/CM-SEC $\eta 10^6$	THERMAL CONDUCTIVITY J/CM-SEC-DEG $\lambda 10^6$
			500	441.8	682.6
			510	447.5	691.3
			520	453.1	699.9
			530	458.7	708.5
			540	464.1	716.9
			550	469.6	725.4
			560	475.0	733.8
			570	480.4	742.1
			580	485.7	750.4
			590	491.1	758.6
100	140.6	217.2	600	496.4	766.8
110	152.2	235.1	610	501.6	774.9
120	163.3	252.3	620	506.8	783.0
130	174.0	268.9	630	512.0	791.0
140	184.4	284.8	640	517.2	798.9
150	194.3	300.2	650	522.2	806.7
160	204.0	315.1	660	527.4	814.7
170	213.3	329.4	670	532.4	822.5
180	222.4	343.5	680	537.4	830.2
190	231.2	357.2	690	542.4	837.9
200	239.8	370.4	700	547.4	845.6
210	248.2	383.4	710	552.3	853.3
220	256.4	396.1	720	557.3	860.9
230	264.5	408.6	730	562.2	868.4
240	272.4	420.8	740	567.0	876.0
250	280.1	432.6	750	571.8	883.4
260	287.6	444.4	760	576.6	890.7
270	295.0	455.7	770	581.5	898.2
280	302.4	467.1	780	586.2	905.6
290	309.5	478.2	790	590.9	912.9
300	316.7	489.2	800	595.7	920.2
310	323.7	500.0	810	600.4	927.4
320	330.6	510.7	820	605.0	934.7
330	337.4	521.2	830	609.7	941.9
340	344.1	531.5	840	614.3	949.0
350	350.7	541.7	850	619.0	956.2
360	357.2	551.9	860	623.5	963.2
370	363.7	561.9	870	628.0	970.2
380	370.0	571.6	880	632.7	977.3
390	376.4	581.4	890	637.2	984.3
400	382.6	591.1	900	641.7	991.3
410	388.8	600.6	910	646.2	998.3
420	394.9	610.1	920	650.7	1005.2
430	401.0	619.4	930	655.2	1012.1
440	407.0	628.7	940	659.6	1018.9
450	412.9	637.9	950	664.0	1025.8
460	418.8	647.0	960	668.4	1032.6
470	424.7	656.0	970	672.7	1039.2
480	430.4	664.9	980	677.1	1045.9
490	436.2	673.8	990	681.5	1052.7
			1000	684.9	1058.0

† Calculated for the dilute gas by the Kihara potential with $\gamma = 0.1$, $\sigma = 2.67$ Å, $\epsilon/k = 53.2$°K.

TABLE IV
VISCOSITY AND THERMAL CONDUCTIVITY OF GASEOUS KRYPTON†

TEMPERATURE	VISCOSITY	THERMAL CONDUCTIVITY	TEMPERATURE	VISCOSITY	THERMAL CONDUCTIVITY
K	G/CM-SEC $\eta 10^6$	J/CM-SEC-DEG $\lambda 10^6$	K	G/CM-SEC $\eta 10^6$	J/CM-SEC-DEG $\lambda 10^6$
			500	392.6	146.1
			510	398.8	148.4
			520	404.9	150.7
			530	411.0	152.9
			540	417.0	155.1
			550	422.9	157.3
			560	428.8	159.5
			570	434.6	161.7
			580	440.4	163.8
			590	446.1	166.0
100*	90.3	33.6	600	451.8	168.1
110*	98.6	36.7	610	457.4	170.2
120*	106.9	39.8	620	463.0	172.2
130*	115.2	42.8	630	468.5	174.3
140*	123.6	46.0	640	473.9	176.3
150*	132.1	49.1	650	479.4	178.4
160*	140.5	52.3	660	484.9	180.4
170*	148.9	55.4	670	490.2	182.4
180*	157.4	58.6	680	495.5	184.4
190*	165.8	61.7	690	500.8	186.3
200*	174.2	64.8	700	506.1	188.3
210*	182.6	67.9	710	511.3	190.2
220*	191.0	71.0	720	516.5	192.1
230*	199.2	74.1	730	521.5	194.0
240*	207.3	77.1	740	526.7	196.0
250*	215.4	80.1	750	531.8	197.8
260*	223.4	83.1	760	536.8	199.7
270	231.4	86.1	770	541.8	201.6
280	239.3	89.0	780	546.7	203.4
290	247.1	91.9	790	551.7	205.2
300	254.9	94.8	800	556.6	207.1
310	262.5	97.7	810	561.4	208.9
320	270.1	100.5	820	566.3	210.7
330	277.5	103.2	830	571.1	212.5
340	284.9	106.0	840	575.9	214.3
350	292.2	108.7	850	580.6	216.0
360	299.4	111.4	860	585.4	217.8
370	306.5	114.0	870	590.0	219.5
380	313.6	116.7	880	594.7	221.3
390	320.5	119.3	890	599.4	223.0
400	327.5	121.8	900	604.0	224.7
410	334.3	124.4	910	608.5	226.4
420	341.0	126.9	920	613.0	228.1
430	347.7	129.4	930	617.7	229.8
440	354.4	131.8	940	622.2	231.5
450	360.9	134.3	950	626.7	233.2
460	367.4	136.7	960	631.1	234.8
470	373.8	139.1	970	635.6	236.5
480	380.2	141.4	980*	640.0	238.1
490	386.5	143.8	990*	644.4	239.8
			1000*	647.7	241.0

† Calculated for the dilute gas by the m-6 potential with $m = 17$, $\sigma = 3.50$Å, $\epsilon/k = 226.0$°K.

* There is some uncertainty in these transport coefficients because they have been extrapolated outside the range of the experimental data.

TABLE V

VISCOSITY AND THERMAL CONDUCTIVITY OF GASEOUS XENON†

TEMPERATURE	VISCOSITY	THERMAL CONDUCTIVITY	TEMPERATURE	VISCOSITY	THERMAL CONDUCTIVITY
K	G/CM-SEC $\eta 10^6$	J/CM-SEC-DEG $\lambda 10^6$	K	G/CM-SEC $\eta 10^6$	J/CM-SEC-DEG $\lambda 10^6$
			500	367.3	87.2
			510	373.6	88.7
			520	379.9	90.2
			530	386.1	91.7
			540	392.3	93.2
			550	398.5	94.6
			560	404.7	96.1
			570	410.8	97.5
			580	416.8	99.0
			590	422.8	100.4
100*	89.4	21.2	600	428.7	101.8
110*	96.7	23.0	610	434.6	103.2
120*	103.9	24.7	620	440.4	104.6
130*	111.1	26.4	630	446.2	106.0
140*	118.2	28.1	640	452.0	107.3
150*	125.2	29.7	650	457.7	108.7
160*	132.4	31.4	660	463.4	110.0
170*	139.5	33.1	670	469.0	111.4
180*	146.6	34.8	680	474.7	112.7
190*	153.7	36.5	690	480.2	114.0
200*	160.9	38.2	700	485.8	115.3
210*	168.0	39.9	710	491.2	116.7
220*	175.2	41.6	720	496.7	118.0
230*	182.4	43.3	730	502.1	119.2
240*	189.5	45.0	740	507.5	120.5
250*	196.6	46.7	750	512.9	121.8
260*	203.8	48.4	760	518.2	123.1
270*	211.0	50.1	770	523.5	124.3
280	218.2	51.8	780	528.8	125.6
290	225.3	53.5	790	534.0	126.8
300	232.4	55.2	800	539.2	128.0
310	239.4	56.8	810	544.3	129.3
320	246.4	58.5	820	549.5	130.5
330	253.5	60.2	830	554.6	131.7
340	260.5	61.9	840	559.7	132.9
350	267.4	63.5	850	564.6	134.1
360	274.3	65.1	860	569.7	135.3
370	281.3	66.8	870	574.7	136.5
380	288.1	68.4	880	579.6	137.6
390	295.0	70.0	890	584.6	138.8
400	301.8	71.7	900	589.5	140.0
410	308.6	73.3	910	594.3	141.1
420	315.3	74.9	920	599.1	142.3
430	321.9	76.4	930	604.0	143.4
440	328.5	78.0	940	608.7	144.5
450	335.1	79.6	950	613.5	145.7
460	341.6	81.1	960	618.2	146.8
470	348.1	82.7	970	622.9	147.9
480	354.5	84.2	980*	627.6	149.0
490	360.9	85.7	990*	632.2	150.1
			1000*	635.4	150.9

† Calculated for the dilute gas by the m-6 potential with $m = 24$, $\sigma = 3.73$Å, $\epsilon/k = 382.3$°K.

* There is some uncertainty in these transport coefficients because they have been extrapolated outside the range of the experimental data.

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