

# The Dielectric Constant of Water and Debye-Hückel Limiting Law Slopes

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Experimental values of the dielectric constant of water suggest that, for temperatures greater than 400 K, the integral in the Kirkwood dielectric-constant equation, which involves the intermolecular potential function, is a simpler function of temperature and pressure than of temperature and density. An equation has been fitted to values of this integral calculated from experimental values of the dielectric constant for temperatures from 238.15 K to 823.15 K and to pressures of approximately 500 MPa for temperatures greater than 273 K. The equation for  $\epsilon$  thus has explicit variables  $T$ ,  $\rho$ ,  $p$  and gives a good representation of the available experimental results. The quality of representation of the experimental results has been compared to that of previous correlations of the dielectric constant. The new equation is applicable through wider regions of independent variables than the previous equations and is capable of sufficient accuracy to provide values of Debye-Hückel limiting law slopes which are as accurate as the experimental results allow. Values of Debye-Hückel limiting-law slopes are tabulated.

Keywords: Debye-Hückel limiting law, dielectric constant, thermodynamic properties of aqueous electrolytes, water.

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## 1. Introduction

The quantitative description of the energetics which exist between charged particles requires a quantitative description of the electrostatic permittivity of the medium in which the charges are immersed. It is often customary to express a medium's permittivity as relative to that of a vacuum. This leads to the common description of the static dielectric constant,  $\epsilon$ , or relative permittivity. Many of the theories, or models used to represent

or simulate the physical or thermodynamic properties of electrolyte solutions invoke the assumption that the solvent may be described as a dielectric continuum. When applied to thermodynamic properties of electrolyte solutions, the most often used theory from this group is that of Debye and Hückel.

The combinations of the ubiquity of aqueous electrolyte solutions and the importance of the Debye-Hückel theory in describing the concentration dependence of thermodynamic properties at concentrations approaching infinite dilution lead to an equal importance of having the best possible representation of experimental measurements of the dielectric constant of water as a function of the independent variables. It is important to realize that within the context of treating the concentration dependence of experimentally measurable thermodynamic properties, i.e., the "excess thermodynamic properties,"<sup>1</sup> an acceptable representation of the dielectric constant of water must give not only a good representation of the experimentally observed dielectric constants, but must also give acceptable values of the first and second derivatives of the dielectric constant with respect to temperature and pressure. Table I gives the relation of the Debye-Hückel limiting law slopes for the activity and osmotic coefficient and for the commonly measured apparent molar properties (within the Bradley and Pitzer<sup>2</sup> definitions), to the relative permittivity and volumetric properties for water. Because experimental measurement of the concentration dependence of thermodynamic properties are rarely performed at constant volume, the derivative of the dielectric constant with respect to volume does not appear in Table I.

Previous representations of the dielectric constant measurements for water, over wide ranges of temperature and pressure, have generally fallen into two categories; namely, the dielectric constant has been expressed either as a function of temperature and pressure or as a function of temperature and water density,  $\rho$ . The work of Bradley and Pitzer<sup>2</sup> is the most often cited example of the first case, whereas the equation of Uematsu and Franck<sup>3</sup> is a recent example of the second case.

Each of the two particular forms of representation has advantages and disadvantages. The temperature derivative of the dielectric constant of water along isochores,  $(\partial\epsilon/\partial T)_v$ , near the critical volume, remains finite through the critical point of water. Along isobars near the critical pressure the temperature derivative,  $(\partial\epsilon/\partial T)_p$ , exhibits large values which approach an infinity as the critical point is approached. This behavior might appear to make the  $T, \rho$  representation of the dielectric constant the simpler of the two methods for an equation that represents the dielectric constant in near-critical and super-critical water. However, the  $T, \rho$  representation requires a transformation of independent variables from those usually measured, namely temperature and pressure. This particular transformation of variables requires a representation of the volumetric properties of water. The equation of state used for the transformation of variable must represent the volumetric properties of water as faithfully as possible. The derivatives of the density of water calculated from the equation of state must also be as

TABLE 1. Debye-Hückel limiting law equations.<sup>a</sup>

activity coefficient	$A_\gamma$	$e^3(2\pi N_A \rho)^{1/2}(4\pi\epsilon\epsilon_0 kT)^{-3/2}$
osmotic coefficient	$A_\phi$	$e^3(2\pi N_A \rho)^{1/2}(4\pi\epsilon\epsilon_0 kT)^{-3/2}/3$
apparent molar volume	$A_V$	$-2A_\phi RT[3(\partial\epsilon/\partial p)_T/\epsilon - (\partial\rho/\partial p)_T/\rho]$
apparent molar enthalpy	$A_H$	$-6A_\phi RT[1 + T(\partial\epsilon/\partial T)_p/\epsilon + T(\partial\rho/\partial T)_p/3\rho]$
apparent molar compressibility	$A_K$	$(\partial A_V/\partial p)_T$
apparent molar heat capacity at constant pressure	$A_C$	$(\partial A_H/\partial T)_p$

<sup>a</sup> $e$  is the charge of an electron,  $1.6021773E-19$  C and  $\epsilon_0$  is the permittivity of vacuum,  $8.8541878E-12$  C<sup>2</sup>J<sup>-1</sup>m<sup>-1</sup>.

accurate as possible, since the derivatives of the dielectric constant depend upon these quantities. Uncertainty in the Debye-Hückel limiting law slopes due to errors in the calculated temperature and pressure derivatives of the density of water thus become magnified. Additionally, it is well known that  $(\partial\rho/\partial T)_p$  changes sign near 277 K (0.1 MPa), the precise temperature being dependent upon the pressure, whereas  $(\partial\epsilon/\partial T)_p$  does not.

In addition to the above differences inherent in the choice of  $T$ ,  $\rho$  and  $T$ ,  $p$  as variables for representations of the dielectric constant, differences in the data chosen for fitting, the weighting of the fitted data, and the range of  $T$ ,  $p$  variables over which data were fitted affect representations of the experimental results. Therefore it is not surprising that differences in Debye-Hückel limiting law slopes are found when they are calculated using different representations of the dielectric constant for water. The effect of Debye-Hückel limiting law slopes obtained from the Bradley and Pitzer<sup>2</sup> equation and from the Uematsu and Franck<sup>3</sup> equation on calculated thermodynamic properties has been noted elsewhere.<sup>4-8</sup>

Previous work<sup>9,10</sup> noted the differences in Debye-Hückel limiting law slopes that resulted from the use of the dielectric constant equations of Uematsu and Franck<sup>3</sup> and of Bradley and Pitzer.<sup>2</sup> Each recommended one or the other of the equations for use. One<sup>10</sup> recommended use of the equation of Uematsu and Franck<sup>3</sup> based on the acceptance of that equation by a committee of an international organization (I.A.P.S.). The other<sup>9</sup> recommended use of the Bradley and Pitzer<sup>2</sup> equation, in part, because values calculated from their equation were closer to values recommended by a committee of another international body (I.U.P.A.C.) for the temperature range of 273.15 to 333.15 K. The needs of researchers examining electrolyte solution properties outside the range of temperature of 273.15–373.15 K were not considered in the recommendation of Ref. 9. The most important criterion for recommending a particular dielectric-constant representation as preferable to another is the ability of a particular equation to represent the best available data and to do so with acceptable values of derivatives. Both of the references<sup>9,10</sup> made some inter-comparison of the two equations. However, neither

reference described agreement of the dielectric-constant equations with the experimental results.

The present work addresses some of these problems. A new representation of the dielectric constant of water from 238.15 to 823.15 K is reported. Careful attention has been given to the first and second derivatives of this equation so that it would provide values of the Debye-Hückel limiting law slopes that would be as reliable as the presently available experimental values of the dielectric constant permit.

## 2. Representation of Experimental Results

### 2.1. Kirkwood Equation for Dielectric Constant of a Fluid

In 1939, Kirkwood<sup>11</sup> related the effect of intermolecular interactions on the dielectric constant of a fluid. The equation given by Kirkwood was:

$$(\epsilon - 1)(2\epsilon + 1)/9\epsilon = N_A(\alpha + \mu\bar{\mu}/3\epsilon_0 kT)/3V_m \quad (1a)$$

where

$$\mu\bar{\mu} = \mu^2[1 + (N_A/V_m) \int_0^{\pi} \cos\gamma e^{-W/kT} d\omega d\nu] \quad (1b)$$

and where  $\epsilon$  is the dielectric constant,  $\alpha$  is the molecular polarizability,  $V_m$  is the molar volume,  $N_A$  is Avogadro's constant,  $\mu$  is the molecular dipole moment of an arbitrary molecule in the fluid,  $\bar{\mu}$  is a local dipole moment in a small region of fluid about the arbitrary molecule and from which reactive-field contributions have been removed,  $\mu$  is the dipole moment of the molecule in the absence of all electric fields. Within the integral,  $\gamma$  is the angle between dipole moments of an arbitrary pair of dipoles, and  $W$  is the potential of average force acting on the arbitrary pair of molecules.  $T$ ,  $k$  and  $\pi$  have their usual meanings.

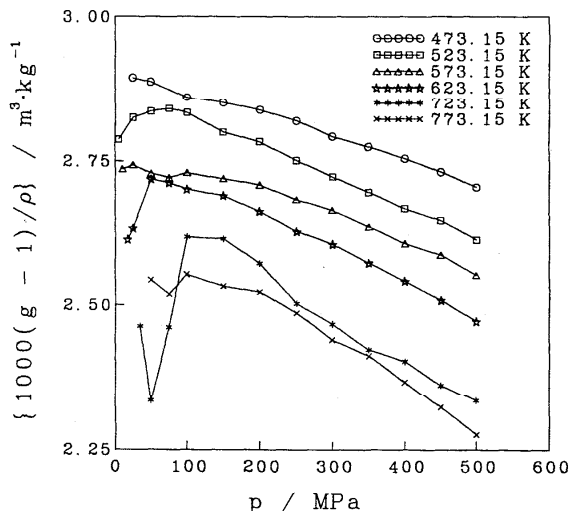
The quantity  $\mu\bar{\mu}$  in Eq. (1) is often replaced with a  $g\mu^2$  and the  $g$  is identified as the "Kirkwood correlation factor" ( $\mu$  is the scalar of the gas-phase dipole moment). For simplicity, substitution of  $g\mu^2$  for  $\mu\bar{\mu}$  will also be used in the current work. In some of the applications of Eq. (1) to experimental results Eq. (1b) does not appear. Equation (1b) is important to the present work.

In principle, the dielectric constant of a fluid can be calculated with a sufficiently refined intermolecular potential of the fluid molecules and Eq. (1). Because of the difficulties inherent in such a calculation, recourse must still be made to empirical representations of experimental results, at least for the present time. Equation (1) was used in the present work for the representation of the dielectric constant of water. The task is one of finding a suitable function that replaces the integral of Eq. (1).

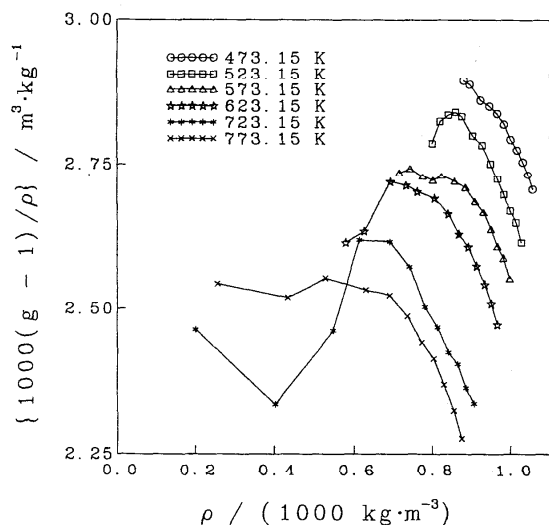
In absence of applicable theory the choice of dependent variables for this function is a matter of convenience. Figure 1a and 1b show the integral portion of Eq. (1), calculated as  $(g - 1)/\rho$  from the data of Heger *et al.*<sup>12</sup> against  $T$  and  $p$  and against  $T$  and  $\rho$ , respectively. As

water density approaches zero the error in  $(g - 1)/\rho$  resulting from error in  $\epsilon$  is magnified. This produces a large degree of scatter in these figures at low pressure and high temperature (Fig. 1a) and low density (Fig. 1b).

$$(g - 1)/\rho = b_0 + b_1 p \quad (2)$$



(a)



(b)

FIG. 1. Values of  $(g - 1)/\rho$  calculated from the dielectric constant results of Heger *et al.*<sup>12</sup> Fig. 1a: against pressure, Fig. 1b: against density.

Some of the experimental values of  $(g - 1)/\rho$ , those at the lowest densities, have values which fell well outside the range of the figure. These unrealistic values of  $(g - 1)/\rho$  were omitted from Figs. 1a and 1b. A linear function:

was fitted to each isothermal set of experimental results for temperatures greater than 373.15 K. In all cases the experimental results were represented to within the authors' stated experimental error by the fitted Eq. (2). A linear relation in  $\rho$  did not fit to the results within experimental error. The experimental results indicate that the integral of Eq. (1) is a simpler function of  $T$  and  $p$  than of  $T$  and  $\rho$ , within experimental error. Values of  $(g - 1)/\rho$  calculated from the recent measurements of Deul,<sup>13</sup> for temperatures greater than 373.15 K, also exhibited a linear pressure behavior. However, the slopes and intercepts obtained from fitting to Deul's<sup>13</sup> measurements are significantly different from those obtained from fitting to Heger *et al.*'s<sup>12</sup> values.

In terms of molecular level interactions, contributions to the dielectric-constant behavior arise from non-dipole-induced polarization, dipole-induced polarization, and rotational restrictions due to dipole-dipole alignments (hydrogen-bonding in water is one example of the latter). These effects all contribute to a local electric field that is oriented in a direction opposing the externally applied field. These effects enter into Eq. (1) through the intermolecular potential function,  $W$ . For water, the dipole-dipole alignments (hydrogen-bonding) are a significant contribution to the dielectric constant for the temperatures of interest here. In order to mimic the effect of water hydrogen-bond formation in the integral of Eq. (1), an exponential term was included in the equation fitted to  $(g - 1)/\rho$ . The purpose of this term was to provide a Boltzmann-like change in extent of hydrogen-bonding of water with respect to temperature and pressure. A multiplicative function of this exponential (e.g. a constant, etc.) was assumed to be able to be subsumed into the exponential. The equation fitted to the values of  $(g - 1)/\rho$  was:

$$\begin{aligned} \rho^0 (g - 1)/\rho = & b_1 p T^{-1} + b_2 T^{-1/2} + b_3 (T - 215 \text{ K})^{-1} \\ & + b_4 (T - 215 \text{ K})^{-1/2} + b_5 (T - 215 \text{ K})^{-1/4} + \\ & \exp(b_6 T^{-1} + b_7 T^{-2} + b_8 p T^{-1} + b_9 p T^{-2}) \end{aligned} \quad (3)$$

where the  $b_i$  were the adjustable parameters and  $\rho^0 = 1000 \text{ kg m}^{-3}$ . Equation (1) also indicates that  $(g - 1)/\rho$  should approach zero as temperature approaches infinity (at least for un-ionized water, because  $W$  should remain finite). However, without an effective intermolecular potential function, it is not known how the integral approaches zero, i.e. the temperature dependence of  $W$  as  $T$  approaches infinity is unknown. Thus, this condition was not built into Eq. (3). The function  $(T - 215 \text{ K})$ , which appears in Eq. (3), is an empirical choice which improved agreement of fitted equation to experiment. It is noted that extrapolation of Eq. (3) to temperatures somewhat smaller than those of the fitted results will probably produce unrealistic effects and thus should be avoided. Equation (3) was fitted to the values of  $(g - 1)/\rho$  obtained from the experimental results by

means of a nonlinear least-squares fitting procedure. The least-squares estimated  $b_i$  are given in Table 2.

The equivalent of weighting factors were calculated from estimated errors assigned to each data set. An error in  $(g - 1)/\rho$ ,  $\sigma$ , was calculated from the estimated error in  $\epsilon$ ,  $\sigma_{\text{exp}}$ , assigned to each set of experimental results. The weighting factor is defined as  $1/\sigma^2$ . The values of  $\sigma_{\text{exp}}$  are found in Table 3. The choice of fitting function is not unique. Values of the static dielectric constant and of Debye-Hückel limiting law slopes, calculated from Eqs. (1) and (3), are given in Tables 4 through 9 (found at the end of the paper).

TABLE 2. Least-squares estimated parameters for Equation (3).

Parameter	Value
$b_1$	$-4.044525 \text{ E}-2 \text{ K MPa}^{-1}$
$b_2$	$103.6180 \text{ K}^{1/2}$
$b_3$	$75.32165 \text{ K}$
$b_4$	$-23.23778 \text{ K}^{1/2}$
$b_5$	$-3.548184 \text{ K}^{1/4}$
$b_6$	$-1246.311 \text{ K}$
$b_7$	$263307.7 \text{ K}^2$
$b_8$	$-6.928953 \text{ E}-1 \text{ K MPa}^{-1}$
$b_9$	$-204.4473 \text{ K}^2 \text{ MPa}^{-1}$

Constants required for calculation of Eq. (1):

$$\alpha = 18.1458392 \times 10^{-30} \text{ m}^3;$$

$$\mu = 6.1375776 \times 10^{-30} \text{ C}\cdot\text{m}; N_A = 6.0221367 \times 10^{23} \text{ mol}^{-1};$$

$$k = 1.380658 \times 10^{-23} \text{ J}\cdot\text{K}^{-1};$$

molecular mass of water =  $0.0180153 \text{ kg}\cdot\text{mol}^{-1}$ .

## 2.2. Equation of state of water

Early in the present work it became apparent that the dependence of  $\rho$  on  $T$  and  $p$  calculated from certain equations of state was introducing unacceptable behavior into the temperature and pressure derivatives of the dielectric constant calculated from some of the trial fitted equations. Figure 2 shows values of  $(\partial^2\rho/\partial p^2)_T$  against pressure for 273.15 K calculated from three equations of state.<sup>14-16</sup> Also shown in Fig. 2 is  $(\partial^2\rho/\partial p^2)_T$  calculated from a polynomial fit to the values of the density of water given by Kell and Whalley<sup>17</sup> in their Tables 1, 3, and 4 for 273.15 K. The polynomial fit gave a root-mean-square error of  $4.5 \times 10^{-3} \text{ kg}\cdot\text{m}^3$ , approximately the experimental error in the values. Haar *et al.*'s<sup>14</sup> equation gives a sigmoidal behavior for this derivative at 273.15 K. For 273.15 K, the pressure dependence of  $(\partial\rho/\partial p)_T$  calculated from Saul and Wagner's<sup>15</sup> equation exhibits a minimum. This minimum becomes more pronounced as temperature decreases from 273 K and less pronounced as temperature increases from 273 K, disappearing at sufficiently large temperature. Hill's equation of state<sup>16</sup> gave the best representation of this property. Because the unusual behavior exhibited by the equations of Haar *et al.*<sup>14</sup> and of Saul and Wagner<sup>15</sup> are not required in order to represent the experimental density data for these conditions, it is considered to be an artifact.

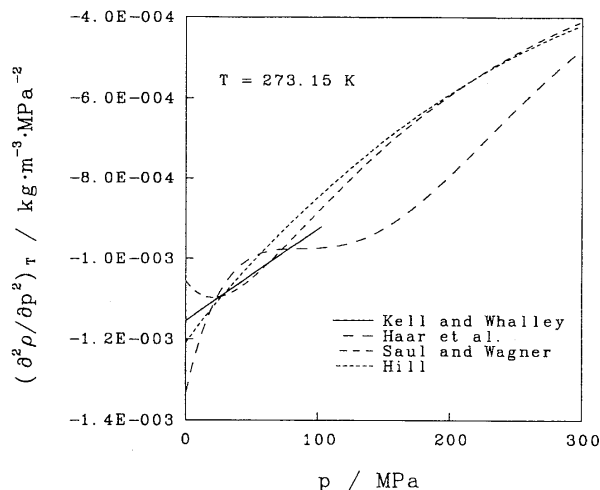


FIG. 2. Values of  $(\partial^2\rho/\partial p^2)_T$  for 273.15 K against pressure calculated from the equations of state of Saul and Wagner,<sup>15</sup> Haar *et al.*,<sup>14</sup> and Hill.<sup>16</sup> Also shown are values calculated from a polynomial in pressure fitted to the density values for 273.15 K given by Kell and Whalley.<sup>17</sup>

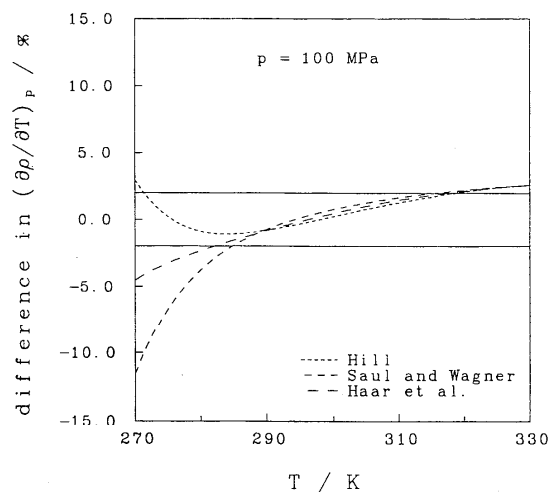


FIG. 3. The difference in values of  $(\partial\rho/\partial T)_p$  for 100 MPa calculated from the equations of state of Saul and Wagner,<sup>15</sup> Haar *et al.*,<sup>14</sup> and Hill<sup>16</sup> from values calculated from Ter Minassian's fitted equation for the expansivity of water for 100 MPa.

Figure 3 compares the difference in  $(\partial\rho/\partial T)_p$  calculated from the equations of Haar *et al.*<sup>14</sup> Saul and Wagner<sup>15</sup> and of Hill<sup>16</sup> to values calculated from the equation for expansivity given by Ter Minassian *et al.*<sup>18</sup> (The temperature at which  $(\partial\rho/\partial T)_p$  is zero is well below 273 K for 100 MPa.) Ter Minassian's equation is a fit to their calorimetrically determined values of expansivity. The

agreement of their measurements to their fitted equation is approximately 1.4%.<sup>18</sup> Ter Minassian showed that the pressure dependence of his expansivities were in excellent agreement with the temperature dependence of Kanno and Angell's<sup>43</sup> compressibility results. The two solid lines in Fig. 3 indicate an experimental uncertainty of  $\pm 2\%$ . Figure 3 shows that the equation of Hill<sup>16</sup> gave the best agreement with Ter Minassian's values, for these conditions. Agreement between Ter Minassian's values and those calculated from Hill's equation becomes somewhat less satisfactory as pressure increases along isotherms.

As a result of these comparisons, and others, the equation of Hill<sup>16</sup> was used for the present work for temperatures above 250 K. At temperatures less than 250 K and for  $p$  of 0.1 MPa the equation of Speedy and Angell<sup>19</sup> was used to calculate the density of water. The effect of substitution of a different equation of state for calculation of Debye-Hückel limiting law slopes is described in a later section.

### 3. Comparison of Fitted Equation with Experimental Results

Results from several experimental studies were included and/or considered for the final least-squares minimization. The experimental studies and their respective temperature and pressure ranges are listed in Table 3. For convenience of description, the fitted results are considered in three groups each of which spans a different range of temperature, namely,  $T < 273.15$  K,  $273.15 \text{ K} < T < 370$  K and  $T > 370$  K.

#### 3.1. $T < 273.15$ K

Four sets of experimental studies were considered for water at temperatures less than 273.15 K and 0.1 MPa, i.e. supercooled water. Hasted and Shahidi<sup>20</sup> and Hodge and Angell<sup>21</sup> measured the dielectric constants of emulsions of water in an inert external phase. In both cases an emulsifying agent was also present. The authors' estimated error for both sets of results was 2 to 3%. This uncertainty was primarily related to separation of the dielectric constant for water from the dielectric constant for the emulsion and to the possibility that some small percentage of the emulsified water droplets had frozen. This error is significantly larger than systematic calibration errors. Both sets of measurements agreed within this error. Hodge and Angell's<sup>21</sup> values joined with the higher temperature values better than those of Hasted and Shahidi.<sup>20</sup> Values of  $(\partial\epsilon/\partial T)_p$  calculated from the two sets of measurements were in good agreement.

The results of Bertolini *et al.*<sup>24</sup> and those of Rusche<sup>30</sup> for water below 273.15 K were obtained for pure water, i.e. the water was not present within an emulsion. Rusche's<sup>30</sup> values are systematically too large over their entire range of temperature. However, the temperature dependence of his dielectric constant values is in excel-

lent agreement with results above 273 K. Bertolini *et al.*<sup>24</sup> apparently calibrated their parallel-plate capacitor system with Malmberg and Maryott's<sup>25</sup> values for the dielectric constant from 273.25 to 303 K. Because Malmberg and Maryott's<sup>25</sup> values are systematically different from most of the other dielectric-constant values (see below), this calibration probably introduces a small systematic error into Bertolini *et al.*'s<sup>24</sup> reported values. Bertolini *et al.*'s<sup>24</sup> values were thus assumed to be accurate to 0.4. Comparison of the experimental values of the dielectric constant and values calculated from the fitted equation are shown in Fig. 4.

TABLE 3. Literature results for the dielectric constant of water.

Reference	$T/\text{K}$	$p/\text{MPa}$	$\sigma_{\text{exp}}^a$	$n^b$	$\sigma_{\text{fit}}^c$
20	238.15–268.15	0.101	3.0	7	1.51
21	238.15–270.83	0.101	3.0	7	0.54
24	256.90–305.50	0.101	0.4	13	0.16
30	268.62–298.23	0.101	0.4	59	0.18
32,33	273.15–313.15	0.101	0.05	6	0.04
28	273.15–323.15	0.1–600	0.05	32	0.05
25	273.25–372.15	0.101	U	21	0.12
29	278.15–338.15	0.1–207	0.2	61	0.09
31	283.15–313.15	0.1–300	0.2	21	0.14
26	273.15–298.15	0.1–100	0.05	66	0.02
27	298.15–343.15	0.1–100	0.05	110	0.02
13	298.15–673.15	***–300	1.0	137	0.21
12	373.15–573.15	***–500	2.0 <sup>d</sup>	40	0.43
12	623.15–823.15	***–500	2.0	65	0.37
23	371.60–642.30 <sup>e</sup>	$p_{\text{sat}}$	2.0	109	0.30
36	637.15–668.75 <sup>f</sup>	19.5–28.8	2.0	33	0.32
37	673.15–873.15 <sup>f</sup>	17.5–58.4	U	23	0.37
38	473.15–623.15	***–202.6	U	22	1.44

<sup>a</sup>  $\sigma_{\text{exp}}$  is the value used to weight each data point in the data set. The letter U indicates that the experimental results were given an insignificant weight in the least-squares procedure; \*\*\*, indicates that the lowest pressure for the data set varied with temperature.

<sup>b</sup>  $n$  is the number of fitted data points in the data set.

<sup>c</sup>  $\sigma_{\text{fit}}$  is the root-mean-square deviation of the experimental results from the fitted Eqs. (1) and (3).

<sup>d</sup> Experimental values for 373.15 K and pressures greater than 250 MPa were given insignificant weight.

<sup>e</sup> Experimental values for temperatures greater than 642.3 K were not included in the least-squares procedure. The dielectric constant equation of Ref. 22 does not give a good representation of the dielectric constant measurements of Ref. 23.

<sup>f</sup> Independent variables were  $T$  and  $p$ .

#### 3.2. $273.15 \leq T < 370$ K

Dielectric-constant values for this temperature range are, in general, significantly more accurate than for the other two temperature ranges.

Figure 5 shows the difference of experimental results from the fitted equation for this temperature range and for 0.1 MPa. The results of Vidulich *et al.*,<sup>32</sup> as later adjusted by Kay *et al.*,<sup>33</sup> Cogan,<sup>27</sup> Milner,<sup>26</sup> (for the

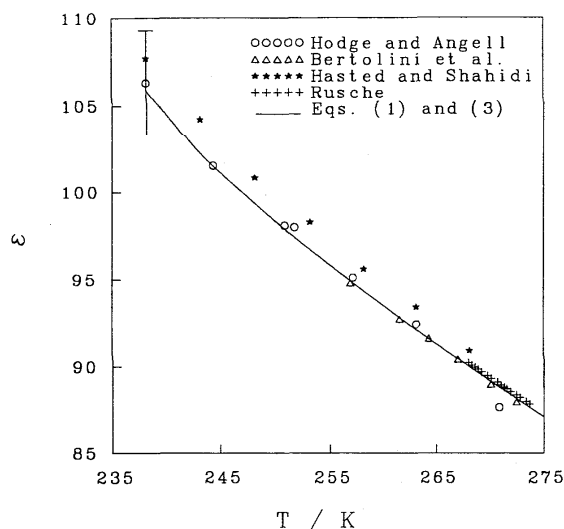


FIG. 4. Values of the dielectric constant of water for 0.1 MPa and against temperature. Error bar represents Hodge and Angell's<sup>21</sup> estimated uncertainty in their values.

purpose of the figures the results of Cogan and Milner are not displayed separately, but together as Owen *et al.*<sup>34</sup>) and Lees<sup>28</sup> agree with the fitted equation to within approximately 0.05. The results of Malmberg and Maryott<sup>25</sup> and of Dunn and Stokes<sup>29</sup> show temperature dependences which are different from these other measurements but yet are remarkably similar to each other. The results of Rusche<sup>30</sup> are systematically larger than the other results for the same temperatures and

approximately 0.2 larger than the fitted equation. The results of Bertolini *et al.*<sup>24</sup> were obtained from a calibration of experiment with the results of Malmberg and Maryott<sup>25</sup> and thus agree with those results but not the results of others.

Kaatz and Uhlendorf<sup>35</sup> reported values of the static dielectric constant obtained from analysis of the frequency dependence of the complex dielectric constant for temperatures from 269.05 to 333.15 K and for 0.1 MPa. The values of Vidulich *et al.*<sup>32</sup> and Owen *et al.*<sup>34</sup> were used by Kaatz and Uhlendorf in their analysis. It was not clear to what extent these earlier values affected the extrapolation to low frequency, i.e. whether there exists independence of Kaatz and Uhlendorf's static dielectric constant values from the literature values. Thus, the Kaatz and Uhlendorf values were not included in the fit to data. Three of the values given by Kaatz and Uhlendorf do not appear to depend on the lower frequency measurements. These three values are different from Eqs. (1) and (3) by: 269.05 K,  $-0.34$ ; 277.15 K,  $-0.32$ ; 294.15 K,  $-0.14$ . The other values agree to within approximately 0.05.

Figure 6 shows the difference of experimental results from the fitted equation against pressure for 298.15 K. The difference between the fitted equation and the experimental results of Cogan,<sup>27</sup> Milner,<sup>26</sup> Srinivasan<sup>31</sup> and of Dunn and Stokes<sup>29</sup> shows a parallel trend. This parallel behavior indicates that these experimental results give values of the pressure dependence of the dielectric constant which agree with each other, despite systematic differences in the absolute value of the dielectric constant. The recent results of Deul<sup>13</sup> show differences which become systematically larger as pressure increases. These differences are as large as 0.55 from the other data sets and 0.45 from the fitted equation.

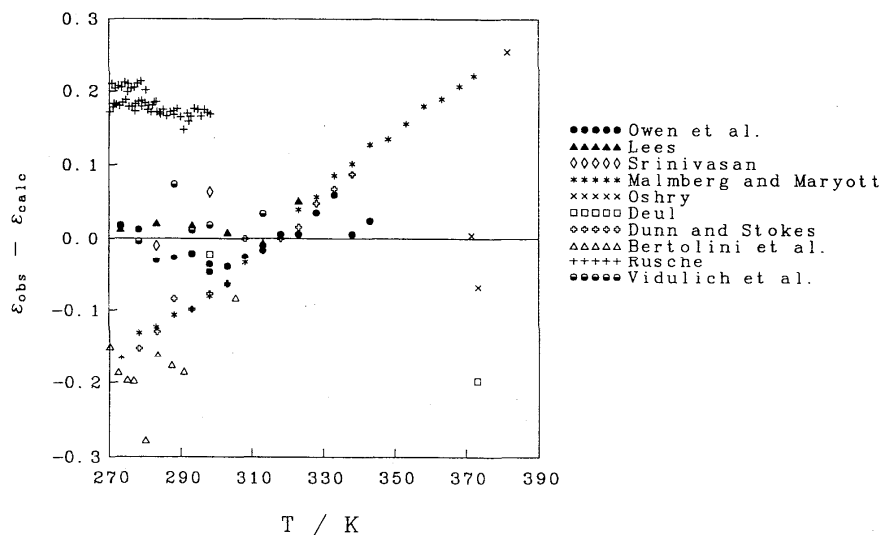


FIG. 5. Residual plot showing the differences between the experimental values of the dielectric constant and the fitted equation against temperature and for pressures of approximately 0.1 MPa.

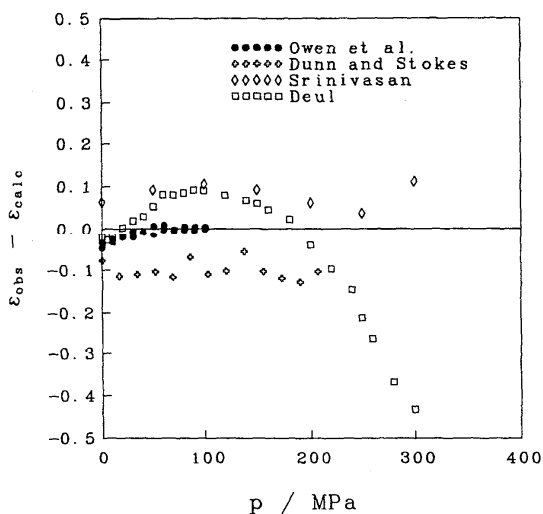


FIG. 6. Residual plot showing the differences between the experimental values of the dielectric constant and the fitted equation against pressure and for 298.15 K.

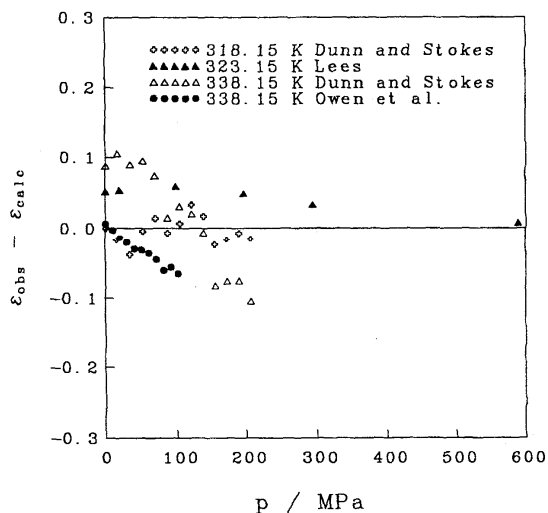


FIG. 8. Residual plot showing the differences between some of the experimental values of the dielectric constant and the fitted equation against pressure and for temperatures of 318.15 to 338.15 K.

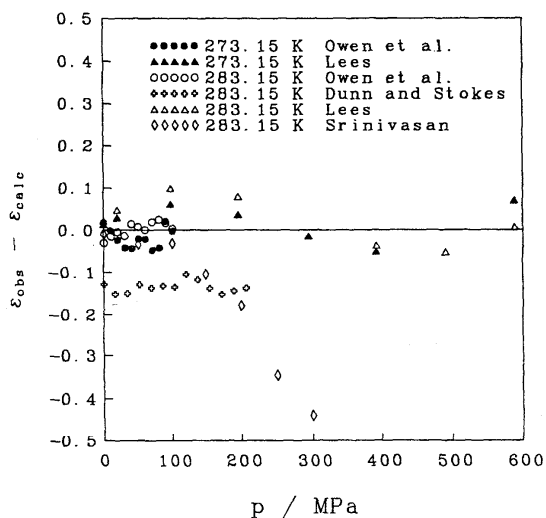


FIG. 7. Residual plot showing the differences between the experimental values of the dielectric constant and the fitted equation against pressure and for temperatures of 273.15 to 283.15 K.

Figure 7 shows the agreement of fitted function to experiment, against pressure, at temperatures near the 0.1 MPa freezing point of water. The experimental values of Srinivasan<sup>31</sup> exhibit a pressure dependence somewhat different than the other results. The good agreement of the equation with the pressure dependence of the experimental values, exhibited in Figs. 6 and 7, continues to temperatures of approximately 323 K. However, for temperatures of 338.15 and 343.15 K, there appear some small systematic discrepancies between the fitted equation and the experimental values (Fig. 8). These differences occurred because the pressure dependence of the high temperature results,  $T > 370$  K, does not match well with the results at 338.15 and 343.15 K. Bradley and Pitzer<sup>2</sup> also observed the existence of this discrepancy. Above 370 K, the data considered by Bradley and Pitzer consisted only of the results of Heger *et al.*<sup>12</sup> The more recent results of Deul<sup>13</sup> give pressure derivatives which are in poorer agreement with the low temperature results than are the pressure derivatives from Heger *et al.*'s results. Therefore, these newer results have not helped to resolve the overlap problem.

### 3.3. $T > 370$ K

The difference between the fitted equation and experiment for pressures near the saturation pressure is shown against temperature in Fig. 9. This figure shows that the



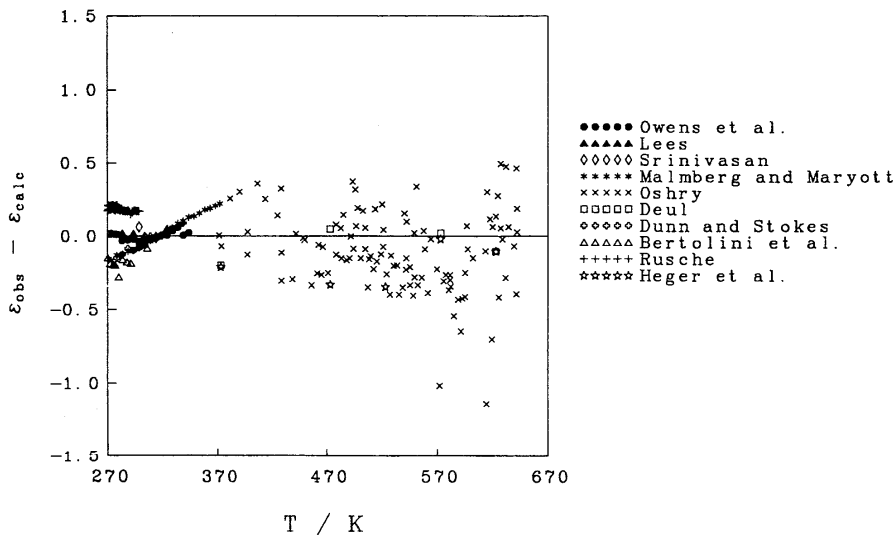


FIG. 9. Residual plot showing the differences between the experimental values of the dielectric constant and the fitted equation against temperature and for pressures near the saturation pressure.

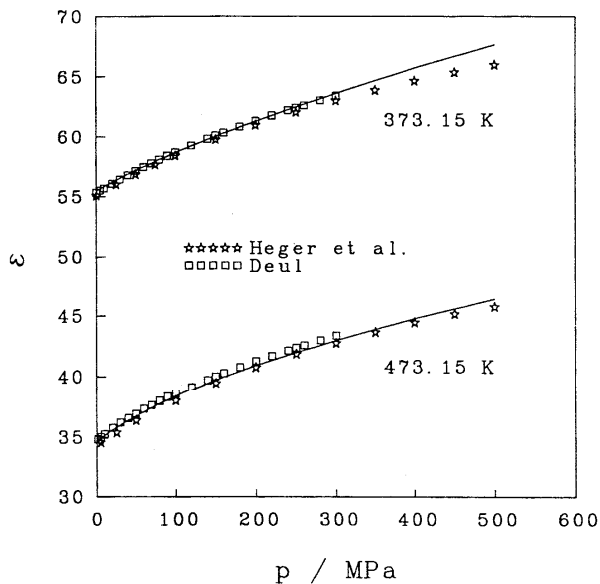


FIG. 10. Comparison of the fitted equation and the experimental dielectric constants against pressure for 373.15 and 473.15 K.

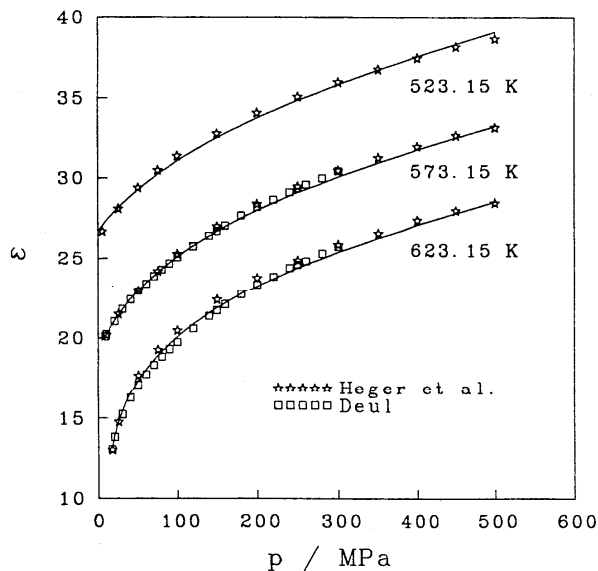


FIG. 11. Comparison of the fitted equation and the experimental dielectric constants against pressure for 523.15, 573.15 and 623.15 K.

temperature dependence of the results of Malmberg and Maryott<sup>25</sup> and of Dunn and Stokes<sup>29</sup> for temperatures less than 370 K also did not agree with the temperature dependence of the experimental results for temperatures greater than 370 K. For this reason the results of Malmberg and Maryott were given an insignificant weight in the fit to data.

Figure 10 compares the experimental results of Heger *et al.*,<sup>12</sup> Deul,<sup>13</sup> and the fitted equation for 373.15 and 473.15 K. The difference for the results of Heger *et al.* are as large as 1.27 for 373.15 K and 500 MPa. For these conditions, Bradley and Pitzer<sup>2</sup> also observed significant differences between Heger *et al.*'s results and their equation. The results of Heger *et al.* are 0.5 smaller than those of Deul for 300 MPa and for both temperatures. This difference can be seen to be systematic for pressures smaller than 300 MPa. Figure 11 shows results at 523.15, 573.15 and 623.15 K. The trend of Heger *et al.*'s results being smaller than those of Deul, as in Fig. 10, inverted for these temperatures and persisted at 673.15 K (Fig. 12). From 373.15 K to 673.15 K, the more recent results of Deul were assumed to have an accuracy twice that of Heger *et al.*'s results. This, combined with the larger number of results reported by Deul, resulted in the fitted equation agreeing better with the Deul results. The systematic difference between Heger *et al.*'s results for 673.15 K and the fitted equation remained for the larger temperatures (Fig. 12). Allowing the fitted equation to represent the Deul results at 673.15 K and then the Heger *et al.* results at 723.15 K would have resulted in values of  $(\partial\epsilon/\partial T)_p$  which would not have agreed well with values from the individual experimental studies. Figure 13 shows values of  $(\partial\epsilon/\partial p)_T$  for 673.15 K calculated from the fitted Eqs. (1) and (3) and from the fitting of Eq. (2) to each of the 673.15 K isothermal sets of measurements. The fitted Eqs. (1) and (3) gave values intermediate to those from the individual fits.

The results of Fogo *et al.*<sup>36</sup> span a very small region of temperature and pressure in the vicinity of the critical region of water. The root mean square deviation of their values from the fitted equation was 0.32. Fogo *et al.*<sup>36</sup> believed that an agreement with their values of 0.6 was good agreement. Figure 14 shows a comparison between the results of Fogo *et al.*<sup>36</sup> and Eqs. (1) and (3) for 650 K and against  $p$ . This temperature is within 3 K of the critical temperature. The results of Fogo *et al.*<sup>36</sup> have a tendency to be slightly smaller than values calculated from the fitted equation. This is in contrast to the tendency of the values of Heger *et al.*<sup>12</sup> to be slightly larger than the fitted equation for this range of density, as shown for 673 K in Fig. 14.

Some of the values of Lukashov *et al.*<sup>37</sup> yield values of  $g$  which are unrealistic. Thus, this data set was given no weight in the fit to data. The root mean square (r.m.s.) deviation for these results was 0.37, with residuals of increasing error with increasing density. The results of Gier and Young<sup>38</sup> for 473 to 623 K were also given no significant weight in the fit to data. These results show a r.m.s. deviation of 1.45 from the equation.

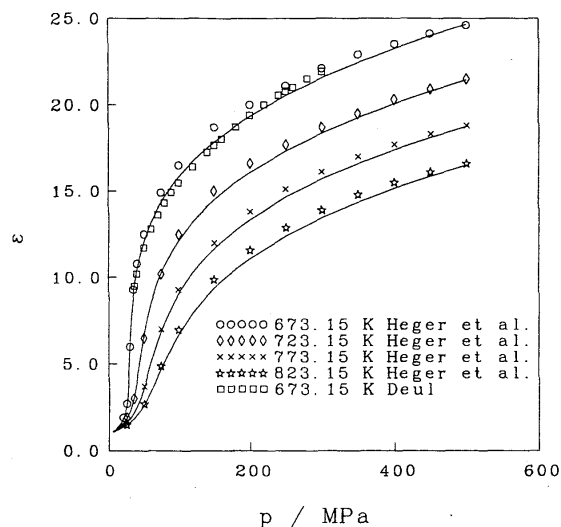


FIG. 12. Comparison of the fitted equation and the experimental dielectric constants against pressure for 673.15, 723.15, 773.15 and 823.15 K.

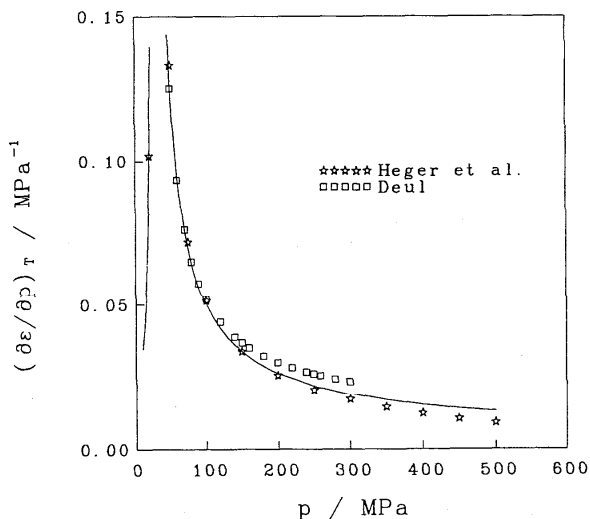


FIG. 13. Values of  $(\partial\epsilon/\partial p)_T$  against pressure for 673.15 K. The values for Heger *et al.*<sup>12</sup> and Deul<sup>13</sup> were calculated from Eq. (2) fitted to each of the 673.15 K sets of experimental results. The line is calculated from the fitted Eqs. (1) and (3).

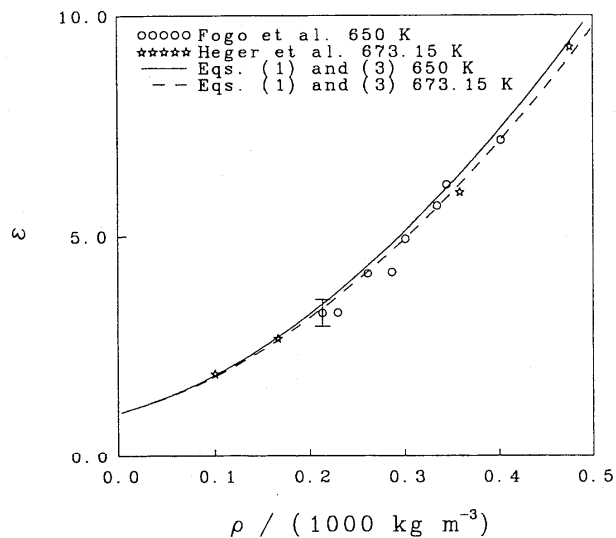


FIG. 14. Comparison of the experimental results of Fogo *et al.*<sup>36</sup> for 650 K with Eqs. (1) and (3) against density. Also shown are the 673.15 K results of Heger *et al.*<sup>12</sup> The error bar is the root mean square deviation of the results of Fogo *et al.* from the fitted equation.

Deul<sup>13</sup> did not discuss the differences between his results and those of Heger *et al.*<sup>12</sup> or those at 298.15 K and large pressure. One suggestion for the differences from Heger *et al.*'s results has been that there may have been significant corrosion in Heger *et al.*'s apparatus. At tem-

peratures near ambient the presence of ions in water lowers the dielectric constant of an aqueous ionic solution compared to water. Heger *et al.*'s results are smaller than Deul's only for 373 and 473 K, temperatures for which corrosion effects would be expected to be smallest. Thus, it does not seem immediately apparent that the differences between Deul's and Heger *et al.*'s results was attributable to corrosion effects in Heger's apparatus.

#### 4. Comparison of Fitted Equation to Previous Equations

The dielectric-constant equation provided here is valid over a wider range of independent variables than the previous equations of Bradley and Pitzer,<sup>2</sup> Uematsu and Franck,<sup>3</sup> and Helgeson and Kirkham.<sup>39</sup> Additionally, Eqs. (1) and (3) required significantly fewer variable parameters than were used in the equation of Helgeson and Kirkham and approximately the same number as used by Pitzer and Bradley and by Uematsu and Franck.

Due to the large number of dielectric-constant measurements and the nature of the calibration errors associated with these measurements, it is not particularly informative to consider the agreement between previous correlations of the dielectric constant and the experimental results. All of the three previous dielectric-constant representations, which will be considered here, were able to reproduce the fitted dielectric-constant results to at least 0.5% for temperatures from 273.15 to 353.15 K. A more severe, but none-the-less useful, test of these dielectric-constant equations is the comparison of temperature

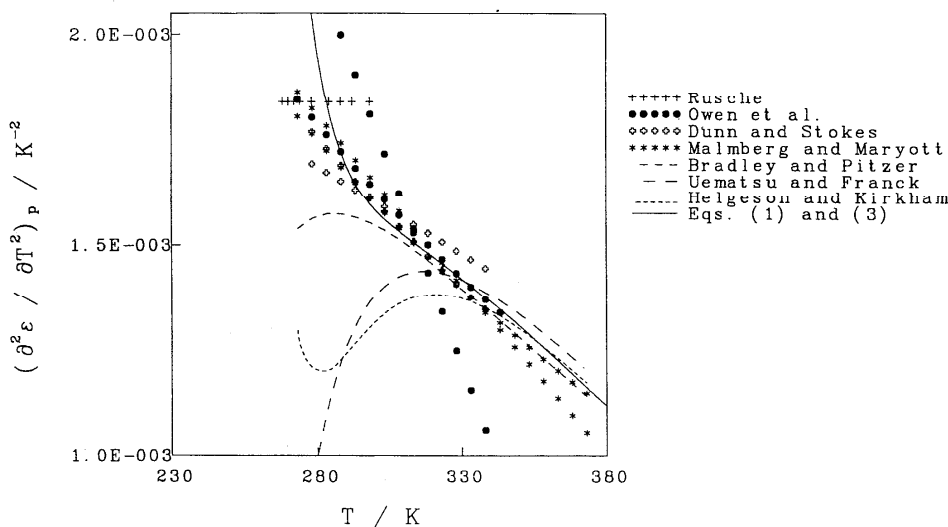


FIG. 15. Comparison of values of  $(\partial^2\epsilon/\partial T^2)_p$  calculated from the dielectric constant equations of Helgeson and Kirkham,<sup>39</sup> Uematsu and Franck,<sup>3</sup> Bradley and Pitzer<sup>2</sup> and Eqs. (1) and (3) against temperature for 0.1 MPa. Values from experimental sources calculated as described in the text.

and pressure derivatives to the range of values of these derivatives which can be reasonably supported by experimental results. Because the first and second derivatives of these equations with respect to temperature and pressure are important for the purpose of calculation of values of the Debye-Hückel limiting law slopes (for some of the experimentally accessible properties), comparison of these derivatives is particularly appropriate. In this section, the range of values of the second derivatives with respect to temperature and pressure which could be supported by experiment are presented. These values were compared to values of the second derivatives of  $\epsilon$  calculated from the present dielectric-constant equation and some of those available in the literature.

Values of the temperature and pressure derivatives of a response function can be calculated from an equation fitted to the response function. In principle, a standard deviation of these derivatives may also be calculated from the standard deviations of the parameters, if the model is linear in its parameters. However, the standard deviations of the derivatives are correct only if the response-function model itself is correct, i.e. if there exists no model bias. In order to avoid the possibility of standard deviations of these derivatives which could be misleading, a different method was applied for the present work. Appropriate sets of experimental results were fitted with more than one equation. Derivatives of the different fitted functions could then be compared to show the effect of model bias in the calculation of the derivatives.

The following two equations have been fitted to isobaric sets of experimental dielectric constants:

$$\epsilon = b_0 + b_1(T - T_r) + b_2(T - T_r)^2 + b_3(T - T_r)^3 \quad (4)$$

$$\epsilon = \exp\{b_0 + b_1(T - T_r)\} \quad (5)$$

where  $T_r$  was selected as 273.15 K. These two equations were fitted to the 0.1 MPa experimental results of Owen *et al.*,<sup>34</sup> Dunn and Stokes<sup>29</sup> and Malmberg and Maryott.<sup>25</sup> Values of  $(\partial^2\epsilon/\partial T^2)_p$  calculated from these fitted equations are shown in Figs. 15 and 16. The results of Rusche,<sup>30</sup> Bertolini *et al.*,<sup>24</sup> Hodge and Angell,<sup>21</sup> and Hasted and Shahidi<sup>20</sup> were fitted with the quadratic analog of Eq. (4). The scatter of the experimental results in these latter sets prevents determination of the cubic term of Eq. (4). The values of  $(\partial^2\epsilon/\partial T^2)_p$  from these latter data sets are shown in the figures as constant values across the temperature range spanned by the measurements.

Values of  $(\partial^2\epsilon/\partial p^2)_T$  were calculated from equations of the form:

$$\epsilon = b_0 + b_1p + b_2p^2 + b_3p^3 \quad (6)$$

$$\epsilon = b_0 + b_1\ln(1 + p/b_2) \quad (7)$$

fitted to the isothermal sets of experimental results of Srinivasan,<sup>31</sup> Dunn and Stokes,<sup>29</sup> and Lees.<sup>28</sup> The results

of Srinivasan<sup>31</sup> and Dunn and Stokes<sup>28</sup> could not define values of the cubic term in pressure and thus the quadratic analog of Eq. (6) was fitted to these results. Eqs. (6) and (7) were also fitted to the experimental results of Heger *et al.*<sup>12</sup> and Deul<sup>13</sup> for 373.15 K. Eqs. (2) and (7) were fitted to the experimental results for 473.15 K. The values of  $(\partial^2\epsilon/\partial p^2)_T$  against temperature, for 0.1 MPa or the saturation pressure, calculated from these fitted equations, are shown in Fig. 17. Also shown in Fig. 17 are values of  $(\partial^2\epsilon/\partial p^2)_T$  calculated from the four dielectric-constant representations. (In Figs. 15–17, the values described as being from Uematsu and Franck were calculated from Uematsu and Franck's equation in  $T$  and  $p$  combined with the equation of state of Haar *et al.*<sup>14</sup> This procedure follows the recommendation of Haar *et al.*<sup>14</sup> and of Beyer and Staples.<sup>10</sup> This procedure was not recommended by Uematsu and Franck and may or may not introduce an additional difference of these values from those calculated from the experimental results, for this specific case.)

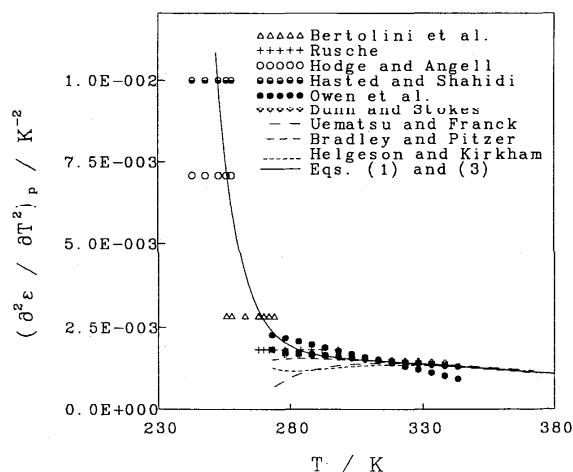


FIG. 16. Comparison of values of  $(\partial^2\epsilon/\partial T^2)_p$  calculated from the dielectric constant equations of Helgeson and Kirkham,<sup>39</sup> Uematsu and Franck,<sup>3</sup> Bradley and Pitzer<sup>2</sup> and Eqs. (1) and (3) against temperature for 0.1 MPa. Values from experimental sources were calculated as described in the text.

From Fig. 15 it is seen that, for temperatures less than 320 K and 0.1 MPa, values of  $(\partial^2\epsilon/\partial T^2)_p$  calculated from the equations of Helgeson and Kirkham<sup>39</sup> and Uematsu and Franck<sup>3</sup> do not agree with the range of values supported by the experimental results. Values of  $(\partial^2\epsilon/\partial T^2)_p$  calculated from the equation of Bradley and Pitzer<sup>2</sup> begin to disagree with the experimental values for  $T < 280$  K.

Debye-Hückel limiting law slopes for apparent molar heat capacity at constant pressure,  $C_{p,\phi}$ , for temperatures

less than 265 K (0.1 MPa), calculated from Eqs. (1) and (3) are negative. These negative slopes result, in part, from the behavior of  $(\partial^2\epsilon/\partial T^2)_p$  for temperatures smaller than 273 K, shown in Fig. 16. There exists a minimum in isothermal values of  $A_c$  for temperatures less than 298 K. For 273 K this minimum occurs near 150 MPa and is found at larger pressures as temperature increases. This behavior is probably an artifact arising from the difference of the equation of state for water and Ter Minasian's<sup>18</sup> experimental results.

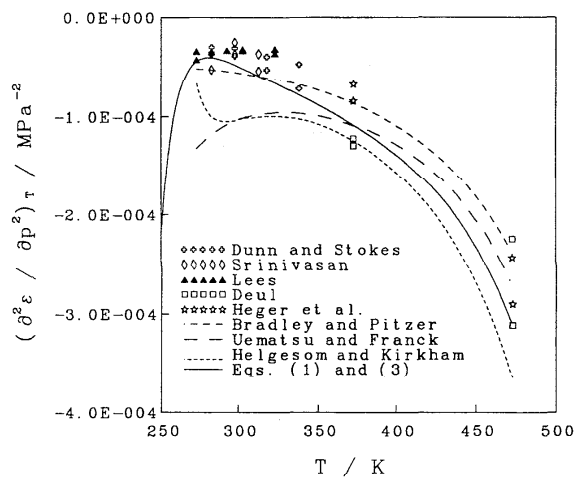


FIG. 17. Comparison of values of  $(\partial^2\epsilon/\partial p^2)_T$  calculated from the dielectric constant equations of Helgeson and Kirkham,<sup>39</sup> Uematsu and Franck,<sup>3</sup> Bradley and Pitzer<sup>2</sup> and Eqs. (1) and (3) against temperature for 0.1 MPa. Values from experimental sources calculated as described in the text.

Figure 17 shows a lack of agreement between values of  $(\partial^2\epsilon/\partial p^2)_T$  for  $T < 360$  K calculated from the equations of Helgeson and Kirkham<sup>39</sup> and Uematsu and Franck<sup>3</sup> with the range of values derived from experiment. For  $T < 280$  K and  $p = 0.1$  MPa, Eqs. (1) and (3) gave values of  $(\partial^2\epsilon/\partial p^2)_T$  which became increasingly negative as  $T$  became smaller. This behavior is not an artifact occurring at the edge of the fitted surface. Instead, this behavior occurs because values of  $(\partial^2\rho/\partial p^2)_T$  calculated from Hill's equation of state of water<sup>16</sup> became substantially more negative as temperature decreases below 280 K. If Speedy's<sup>40</sup> hypothesis concerning the instability limits of water is correct, then  $(\partial^2\rho/\partial p^2)_T$  approaches negative infinity as  $T$  approaches 228 K for 0.1 MPa (228 K being the temperature for which Speedy estimated that the instability locus crosses the 0.1 MPa isobar). The temperature dependence of  $(\partial^2\rho/\partial p^2)_T$  calculated from Hill's<sup>16</sup> equation for 255 K  $< T < 280$  K appears to be compatible with such behavior. This low temperature behavior of  $\epsilon$ , not yet demonstrated experimentally, may be viewed as a theoretical prediction from the Kirkwood equation. This prediction,

of course, can be no more accurate than the equation of state of water in this region of independent variables. For  $T > 400$  K, the range of values compatible with the experimental results is such that the present equation, as well as those of Bradley and Pitzer<sup>2</sup> and Uematsu and Franck<sup>3</sup> can all be said to represent the second derivatives obtained from the experimental results within their respective limits of validity. The pressure dependence of the equation presented here is based somewhat more in theory than the three previous equations,<sup>2,3,35</sup> because of the presence of the molar volume terms in Eq. (1). Thus the present equation should be expected to yield more accurate values of the pressure derivatives of the dielectric constant.

In 1965, Quist and Marshall<sup>41</sup> examined the available dielectric constant measurements and provided a correlation based on the Kirkwood equation. Quist and Marshall's values of the dielectric constant, for temperatures from 673 to 1073 K, average 0.7% smaller than values calculated from Eqs. (1) and (3). The largest difference in this temperature region is approximately -3%. For temperatures above 343.15 K, their equation was based only on the results of Fogo *et al.*<sup>36</sup> and of Akerlof and Oshry.<sup>22</sup> Because the measurements of Oshry<sup>23</sup> were made at saturation pressure and the measurements of Fogo *et al.* were made over a very narrow range of pressure, there were very few measurements available to Quist and Marshall that gave the isothermal pressure dependence of the dielectric constant, for temperatures greater than 343 K. Considering the lack of data available to Quist and Marshall, the agreement between their equation and Eqs. (1) and (3) demonstrates the strength of the Kirkwood-equation approach. Of course, the present equation should be considered more accurate than Quist and Marshall's equation because it is based on a significantly larger base of experimental results.

Pitzer<sup>42</sup> has provided a representation of the dielectric constant results of Heger *et al.*,<sup>12</sup> for temperatures of 673.15 K and larger, which is also based on the Kirkwood equation. Pitzer's Eq. (2) gives values of the integral of Eq. (1) which are independent of temperature at small densities ( $< \approx 300$  kg·m<sup>-3</sup>), a behavior which is doubtful and was recognized as such by Pitzer. The behavior exhibited by the experimental results shown in Fig. 1a casts further doubt on the validity of the low-density temperature independence of the integral of Eq. (1). The present equation which was fitted to the experimental values of the integral of Eq. (1) did not contain this constancy. Instead, the present representation of the integral decays exponentially with temperature through this temperature region. Therefore, it is expected that values of the dielectric constant calculated from Eqs. (1) and (3) for temperatures greater than 850 K should be more accurate than those calculated with Pitzer's Eqs. (1) and (2).

After examination of the dielectric constant of water for a smaller range of independent variables than that considered in the present work, Helgeson and Kirkham<sup>39</sup>

concluded that "... (despite its theoretical origins) the Kirkwood equation is not suitable for comprehensive and accurate representation of the dielectric constant and its partial derivatives over the range of pressures and temperatures considered in this study." This has not been our experience.

### 5. Effect of Substitution of Different Equation of State of Water

It sometimes happens that Debye-Hückel limiting law slopes are calculated from a  $T, \rho$  representation of the dielectric constant combined with an equation of state other than that which was used in the generation of the dielectric-constant equation. One example would be calculation of the derivatives of the dielectric constant with respect to  $T$  and  $p$ , required for the Debye-Hückel limiting law slopes, from the dielectric constant equation of Helgeson and Kirkham<sup>39</sup> combined with the equation of state of Haar *et al.*<sup>14</sup> There is of course a large number of possible permutations of dielectric constant equation and equation of state.

In this section, a comparison is made of Debye-Hückel limiting law slopes calculated from 1) Eqs. (1) and (3) using the equation of state with which Eqs. (1) and (3) were fitted to the dielectric constants and 2) an equation of state which was not used in the representation. Figure 18 shows the percentage difference of  $A_\phi$  calculated using the parameters of Table 2, Eqs. (1) and (3), and the equations of state of Hill<sup>16</sup> and of Saul and Wagner.<sup>15</sup> Differences as large as 0.6 to 0.7 % occur in the temperature region above 873 K.

Figures 19 and 20 show the percentage difference in  $A_H$  and  $A_V$ , respectively, calculated from the parameters of Table 2, Eqs. (1) and (3), and the equations of Hill<sup>16</sup> and Saul and Wagner.<sup>15</sup> There exists a locus of  $T$  and  $p$  across which  $A_H$  and  $A_V$  change sign. This line is slightly different for the two equations of state. Thus, the percentage difference shown in Figs. 19 and 20 would be infinity along this locus. Because this locus of infinities is not important for the present context, it was avoided in the calculations used to prepare Figs. 19 and 20. Errors of several percent result in  $A_H$ , for 273.15 K, from substitution of the equation of Saul and Wagner<sup>15</sup> for the equation with which the experimental results were fitted. Errors in  $A_C$  and  $A_K$  are even larger; differences in  $A_C$  become as large as several hundred percent for the combination of large pressures and temperatures near 273 K. These differences in the Debye-Hückel limiting law slopes are directly related to differences in  $\rho$  and derivatives of  $\rho$ , such as those shown in Figs. 2 and 3.

Of the equations of state examined for the present work<sup>14-16,39</sup> the two most accurate were Hill's<sup>16</sup> and Saul

and Wagner's;<sup>15</sup> yet, significant errors still resulted in the Debye-Hückel limiting law slopes when one equation was substituted for the other without refitting to the data. Errors in calculation of Debye-Hückel limiting law values can be expected to increase when even less accurate equations of state are substituted. Therefore, it is apparent that a  $T, \rho$  representation, or in the present work a  $T, p, \rho$  representation, should only be used with the equation of state which was used in its generation. As better equations of state become available or as new measurements of the dielectric constant become available we will update the parameters of Eq. (1) and (3) in this journal.

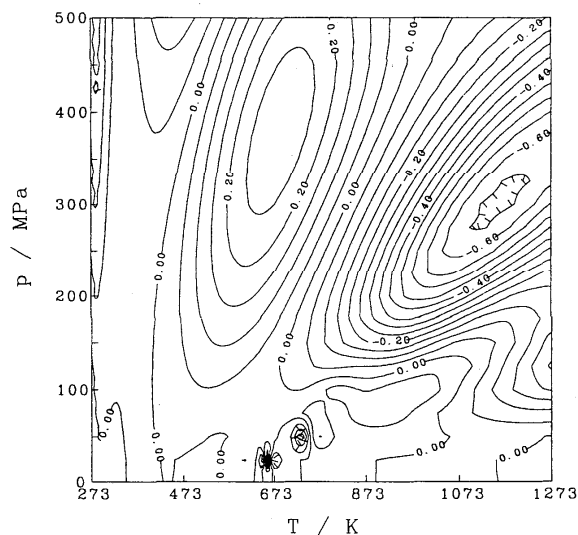


FIG. 18. Contour map of the difference in  $A_\phi$  calculated with Eqs. (1) and (3) after substitution of the equation of state of Saul and Wagner<sup>15</sup> from Eqs. (1) and (3). Contour labels are percent difference. Each contour represents a 0.05% difference in the values of  $A_\phi$ .

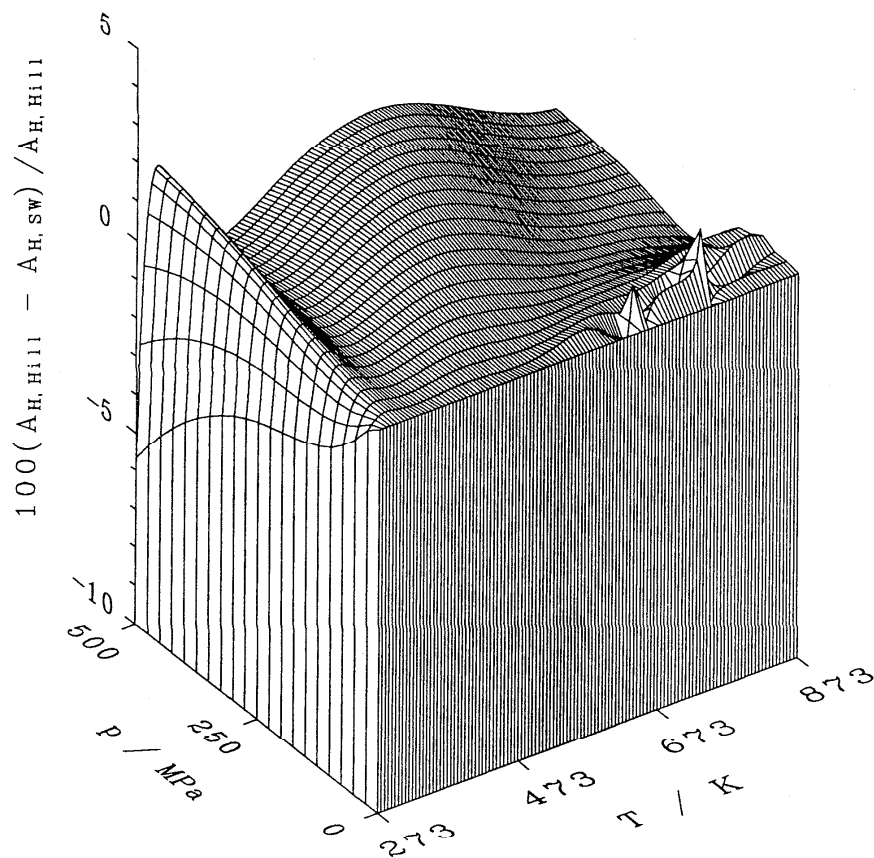


FIG. 19. Surface plot of the difference in  $A_H$  calculated with Eqs. (1) and (3) from that calculated after substitution of the equation of state of Saul and Wagner<sup>15</sup>.

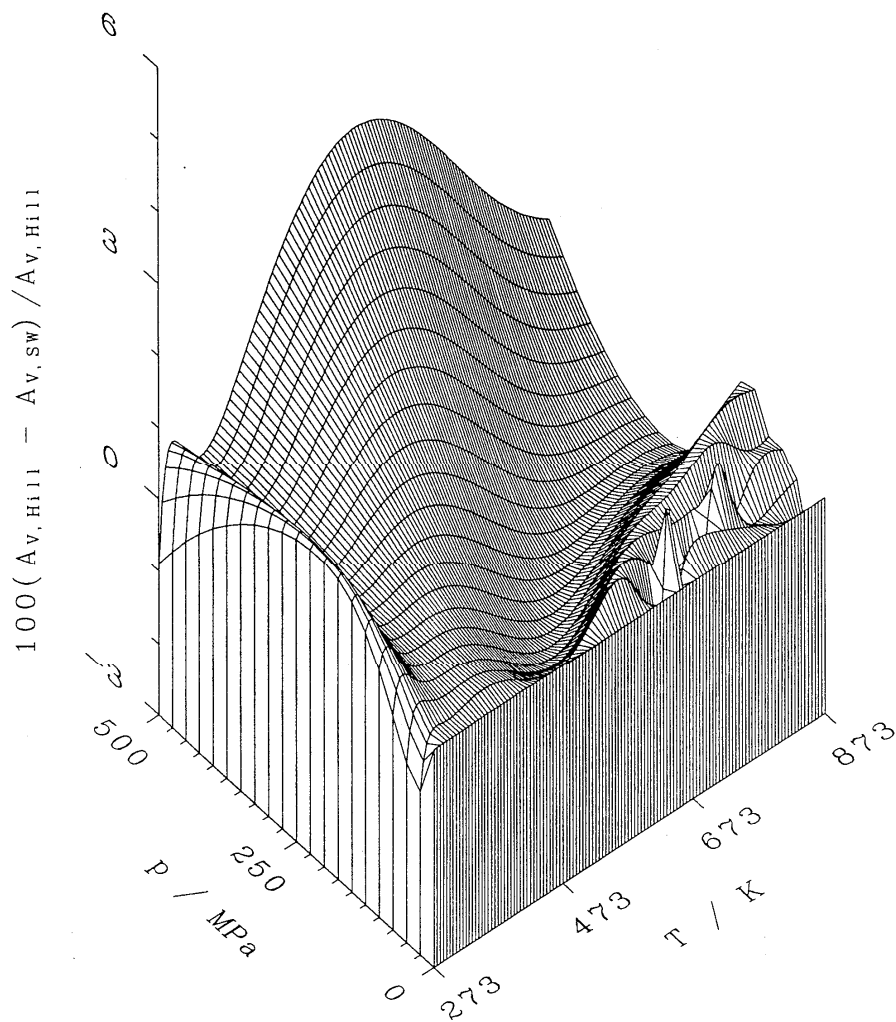


FIG. 20. Surface plot of the difference in  $A_v$  calculated with Eqs. (1) and (3) from that calculated after substitution of the equation of state of Saul and Wagner<sup>15</sup>.



Table 4. Static dielectric constant of water.

T/K	p/MPa									
	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
263.15	92.10									
268.15	89.96	90.00	90.17	90.38	90.80	91.21	91.62	92.02	92.43	92.82
273.15	87.90	87.94	88.10	88.30	88.70	89.10	89.49	89.88	90.27	90.65
278.15	85.90	85.94	86.10	86.29	86.68	87.06	87.45	87.82	88.20	88.57
283.15	83.96	83.99	84.14	84.33	84.71	85.09	85.46	85.83	86.19	86.55
288.15	82.06	82.09	82.24	82.43	82.79	83.16	83.52	83.88	84.24	84.59
293.15	80.20	80.23	80.38	80.56	80.92	81.28	81.64	81.99	82.34	82.69
298.15	78.38	78.41	78.56	78.74	79.10	79.45	79.80	80.15	80.49	80.83
303.15	76.60	76.64	76.78	76.96	77.31	77.66	78.01	78.35	78.68	79.02
308.15	74.86	74.90	75.04	75.22	75.57	75.91	76.25	76.59	76.92	77.25
313.15	73.17	73.20	73.34	73.51	73.86	74.20	74.54	74.87	75.20	75.53
318.15	71.50	71.53	71.68	71.85	72.19	72.53	72.87	73.20	73.52	73.85
323.15	69.88	69.91	70.05	70.22	70.57	70.90	71.24	71.56	71.88	72.20
328.15	68.29	68.32	68.46	68.63	68.98	69.31	69.64	69.97	70.28	70.60
333.15	66.74	66.77	66.91	67.08	67.42	67.75	68.08	68.41	68.72	69.04
338.15	65.22	65.25	65.39	65.56	65.90	66.23	66.56	66.88	67.20	67.51
343.15	63.73	63.77	63.91	64.08	64.42	64.75	65.08	65.40	65.71	66.02
348.15	62.28	62.32	62.46	62.63	62.97	63.30	63.62	63.94	64.26	64.56
353.15	60.87	60.90	61.04	61.21	61.55	61.88	62.21	62.53	62.84	63.14
358.15	59.48	59.51	59.65	59.83	60.17	60.50	60.82	61.14	61.45	61.76
363.15	58.13	58.16	58.30	58.48	58.82	59.15	59.47	59.79	60.10	60.40
368.15	56.81	56.84	56.98	57.15	57.50	57.83	58.15	58.47	58.78	59.08
373.15	55.51	55.55	55.69	55.86	56.20	56.54	56.86	57.18	57.49	57.79
383.15	1.01	53.05	53.19	53.37	53.71	54.05	54.37	54.69	55.00	55.31
393.15	1.01	50.66	50.80	50.98	51.33	51.67	52.00	52.32	52.63	52.93
398.15	1.01	49.50	49.65	49.83	50.18	50.52	50.85	51.17	51.48	51.79
403.15	1.00	48.37	48.52	48.70	49.05	49.40	49.73	50.05	50.37	50.67
413.15	1.00	46.18	46.33	46.52	46.88	47.23	47.56	47.89	48.20	48.51
423.15	1.00	44.08	44.24	44.43	44.79	45.15	45.49	45.82	46.14	46.45
433.15	1.00	42.07	42.23	42.42	42.80	43.16	43.51	43.84	44.16	44.48
443.15	1.00	40.13	40.30	40.50	40.88	41.25	41.61	41.95	42.27	42.59

Table 4 (cont.) Static dielectric constant of water.

T/K	P/MPa									
	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
443.15	1.00	39.20	39.36	39.56	39.96	40.33	40.69	41.03	41.36	41.68
453.15	1.00	1.04	38.44	38.65	39.05	39.42	39.79	40.13	40.47	40.79
463.15	1.00	1.04	36.66	36.87	37.28	37.67	38.04	38.39	38.73	39.06
473.15	1.00	1.04	34.93	35.15	35.58	35.98	36.36	36.72	37.07	37.40
493.15	1.00	1.03	30.86	31.11	31.58	32.02	32.43	32.82	33.19	33.55
523.15	1.00	1.03	27.05	27.34	27.89	28.38	28.84	29.27	29.67	30.05
523.15	1.00	1.03	27.05	27.34	27.89	28.38	28.84	29.27	29.67	30.05
543.15	1.00	1.03	1.19	23.76	24.42	25.00	25.52	26.00	26.44	26.85
573.15	1.00	1.03	1.16	20.22	21.08	21.79	22.41	22.96	23.46	23.91
593.15	1.00	1.02	1.14	1.40	17.72	18.68	19.45	20.10	20.67	21.19
623.15	1.00	1.02	1.13	1.33	13.96	15.52	16.56	17.37	18.05	18.64
643.15	1.00	1.02	1.12	1.28	2.23	11.95	13.62	14.71	15.55	16.24
673.15	1.00	1.02	1.11	1.25	1.83	6.18	10.41	12.04	13.12	13.97
693.15	1.00	1.02	1.10	1.23	1.67	2.90	6.76	9.30	10.76	11.80
723.15	1.00	1.02	1.09	1.21	1.56	2.30	4.10	6.69	8.49	9.74
743.15	1.00	1.02	1.08	1.19	1.49	2.03	3.05	4.75	6.51	7.88
773.15	1.00	1.01	1.08	1.17	1.44	1.86	2.56	3.65	5.03	6.32
793.15	1.00	1.01	1.07	1.16	1.39	1.74	2.27	3.04	4.04	5.13
823.15	1.00	1.01	1.07	1.15	1.36	1.65	2.07	2.66	3.41	4.27
843.15	1.00	1.01	1.06	1.14	1.33	1.58	1.93	2.40	2.98	3.67
873.15	1.00	1.01	1.06	1.13	1.30	1.53	1.83	2.21	2.68	3.23
923.15	1.00	1.01	1.05	1.11	1.26	1.44	1.67	1.95	2.29	2.67
973.15	1.00	1.01	1.05	1.10	1.23	1.38	1.56	1.78	2.04	2.32
1023.15	1.00	1.01	1.04	1.09	1.20	1.33	1.49	1.66	1.87	2.09
1073.15	1.00	1.01	1.04	1.08	1.18	1.29	1.43	1.57	1.74	1.92
1123.15	1.00	1.01	1.04	1.08	1.16	1.26	1.38	1.50	1.64	1.80
1173.15	1.00	1.01	1.03	1.07	1.15	1.24	1.34	1.45	1.57	1.70
1223.15	1.00	1.01	1.03	1.06	1.14	1.22	1.31	1.40	1.51	1.62
1273.15	1.00	1.01	1.03	1.06	1.13	1.20	1.28	1.36	1.46	1.56

Table 4 (cont.) Static dielectric constant of water.

T/K	p/MPa									
	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
273.15	91.03	91.78	93.61	95.37	97.07	98.71	100.30	101.85	103.34	104.78
278.15	88.94	89.67	91.44	93.15	94.81	96.41	97.97	99.47	100.92	102.33
283.15	86.91	87.62	89.35	91.02	92.63	94.20	95.71	97.18	98.59	99.97
288.15	84.94	85.64	87.32	88.95	90.52	92.05	93.53	94.96	96.34	97.68
293.15	83.03	83.71	85.35	86.94	88.48	89.97	91.41	92.80	94.16	95.46
298.15	81.17	81.83	83.44	85.00	86.50	87.95	89.36	90.72	92.04	93.31
303.15	79.35	80.00	81.58	83.10	84.57	85.99	87.36	88.69	89.98	91.23
308.15	77.58	78.22	79.77	81.26	82.70	84.09	85.43	86.73	87.98	89.20
313.15	75.85	76.48	78.01	79.47	80.88	82.23	83.55	84.82	86.05	87.24
318.15	74.16	74.79	76.29	77.73	79.11	80.44	81.72	82.96	84.16	85.33
323.15	72.52	73.13	74.62	76.03	77.38	78.69	79.95	81.16	82.34	83.48
328.15	70.91	71.52	72.98	74.38	75.71	76.99	78.22	79.41	80.57	81.68
333.15	69.34	69.95	71.39	72.77	74.07	75.33	76.54	77.71	78.84	79.94
338.15	67.81	68.41	69.84	71.20	72.49	73.72	74.91	76.06	77.17	78.25
343.15	66.32	66.92	68.33	69.67	70.94	72.16	73.33	74.46	75.55	76.60
348.15	64.87	65.46	66.86	68.18	69.44	70.63	71.79	72.90	73.97	75.00
353.15	63.44	64.03	65.42	66.73	67.97	69.15	70.29	71.38	72.43	73.45
358.15	62.06	62.64	64.02	65.32	66.54	67.71	68.83	69.90	70.94	71.94
363.15	60.70	61.28	62.66	63.94	65.15	66.30	67.41	68.47	69.49	70.47
368.15	59.38	59.96	61.33	62.60	63.80	64.94	66.03	67.07	68.08	69.05
373.15	58.09	58.67	60.03	61.29	62.48	63.61	64.68	65.71	66.70	67.66
383.15	55.60	56.18	57.53	58.77	59.94	61.04	62.09	63.10	64.07	65.00
393.15	53.23	53.81	55.15	56.38	57.53	58.61	59.64	60.63	61.57	62.48
398.15	52.09	52.66	54.00	55.23	56.37	57.44	58.46	59.44	60.37	61.27
403.15	50.97	51.54	52.88	54.10	55.24	56.30	57.31	58.28	59.20	60.09
413.15	48.81	49.39	50.72	51.93	53.06	54.11	55.10	56.05	56.95	57.82
423.15	46.75	47.33	48.66	49.87	50.98	52.02	53.00	53.93	54.82	55.67
433.15	44.78	45.36	46.70	47.90	49.01	50.04	51.00	51.92	52.79	53.63
443.15	42.90	43.49	44.83	46.03	47.13	48.15	49.10	50.00	50.86	51.68

Table 4 (cont.) Static dielectric constant of water.

T/K	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
448.15	41.99	42.58	43.92	45.12	46.22	47.23	48.18	49.08	49.93	50.75
453.15	41.10	41.69	43.04	44.24	45.33	46.34	47.29	48.18	49.03	49.83
463.15	39.38	39.98	41.33	42.53	43.62	44.63	45.56	46.44	47.28	48.07
473.15	37.72	38.33	39.70	40.90	41.99	42.99	43.92	44.79	45.61	46.40
498.15	33.88	34.52	35.92	37.14	38.22	39.21	40.12	40.97	41.78	42.54
523.15	30.41	31.07	32.52	33.76	34.85	35.83	36.74	37.57	38.36	39.10
523.15	30.41	31.07	32.52	33.76	34.85	35.83	36.74	37.57	38.36	39.10
548.15	27.24	27.95	29.46	30.72	31.82	32.81	33.70	34.53	35.30	36.02
573.15	24.33	25.10	26.68	27.98	29.10	30.08	30.98	31.79	32.55	33.27
598.15	21.65	22.48	24.16	25.50	26.63	27.63	28.52	29.33	30.08	30.78
623.15	19.17	20.08	21.86	23.25	24.40	25.40	26.29	27.10	27.84	28.53
648.15	16.84	17.86	19.76	21.20	22.37	23.38	24.27	25.08	25.81	26.50
673.15	14.67	15.80	17.84	19.32	20.52	21.54	22.44	23.24	23.97	24.65
698.15	12.62	13.89	16.08	17.62	18.84	19.87	20.76	21.57	22.29	22.96
723.15	10.70	12.13	14.47	16.06	17.30	18.34	19.24	20.04	20.76	21.42
748.15	8.94	10.51	12.99	14.64	15.90	16.95	17.84	18.64	19.36	20.01
773.15	7.40	9.05	11.66	13.34	14.62	15.67	16.57	17.36	18.07	18.72
798.15	6.13	7.77	10.44	12.16	13.46	14.51	15.40	16.19	16.89	17.54
823.15	5.14	6.69	9.35	11.09	12.39	13.44	14.33	15.11	15.81	16.45
848.15	4.40	5.79	8.38	10.13	11.42	12.47	13.35	14.12	14.81	15.44
873.15	3.84	5.06	7.53	9.25	10.54	11.58	12.45	13.22	13.90	14.52
923.15	3.10	4.01	6.13	7.76	9.01	10.02	10.88	11.62	12.28	12.88
973.15	2.64	3.34	5.09	6.57	7.75	8.73	9.55	10.27	10.90	11.48
1023.15	2.34	2.88	4.33	5.63	6.73	7.65	8.43	9.12	9.73	10.28
1073.15	2.12	2.56	3.76	4.89	5.89	6.75	7.49	8.15	8.73	9.26
1123.15	1.96	2.33	3.33	4.31	5.20	6.00	6.69	7.31	7.87	8.37
1173.15	1.84	2.15	3.00	3.85	4.65	5.37	6.02	6.60	7.13	7.61
1223.15	1.74	2.01	2.74	3.48	4.19	4.85	5.45	5.99	6.49	6.95
1273.15	1.66	1.89	2.53	3.18	3.81	4.41	4.96	5.47	5.94	6.37

TABLE 5. Debye Huckel limiting law slopes for osmotic coefficient  $A_\phi$ , units = (kg/mol)<sup>-1/2</sup>.

T/K	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
263.15	3.7088E-1	3.7073E-1	3.7006E-1	3.6923E-1	3.6758E-1	3.6596E-1	3.6436E-1	3.6279E-1	3.6123E-1	3.5969E-1
268.15	3.7368E-1	3.7353E-1	3.7287E-1	3.7205E-1	3.7042E-1	3.6881E-1	3.6722E-1	3.6565E-1	3.6410E-1	3.6256E-1
273.15	3.7642E-1	3.7627E-1	3.7561E-1	3.7479E-1	3.7316E-1	3.7155E-1	3.6995E-1	3.6837E-1	3.6681E-1	3.6527E-1
278.15	3.7920E-1	3.7905E-1	3.7838E-1	3.7755E-1	3.7590E-1	3.7428E-1	3.7266E-1	3.7107E-1	3.6950E-1	3.6794E-1
283.15	3.8207E-1	3.8191E-1	3.8123E-1	3.8039E-1	3.7872E-1	3.7706E-1	3.7543E-1	3.7381E-1	3.7222E-1	3.7064E-1
288.15	3.8506E-1	3.8490E-1	3.8421E-1	3.8334E-1	3.8164E-1	3.7995E-1	3.7828E-1	3.7664E-1	3.7502E-1	3.7341E-1
293.15	3.8819E-1	3.8803E-1	3.8732E-1	3.8643E-1	3.8468E-1	3.8296E-1	3.8126E-1	3.7958E-1	3.7792E-1	3.7629E-1
298.15	3.9148E-1	3.9131E-1	3.9057E-1	3.8966E-1	3.8787E-1	3.8610E-1	3.8436E-1	3.8264E-1	3.8095E-1	3.7929E-1
303.15	3.9492E-1	3.9474E-1	3.9399E-1	3.9305E-1	3.9120E-1	3.8938E-1	3.8759E-1	3.8584E-1	3.8411E-1	3.8241E-1
308.15	3.9852E-1	3.9834E-1	3.9756E-1	3.9658E-1	3.9468E-1	3.9281E-1	3.9097E-1	3.8917E-1	3.8740E-1	3.8565E-1
313.15	4.0228E-1	4.0209E-1	4.0128E-1	4.0028E-1	3.9831E-1	3.9638E-1	3.9449E-1	3.9264E-1	3.9082E-1	3.8903E-1
318.15	4.0620E-1	4.0601E-1	4.0517E-1	4.0413E-1	4.0209E-1	4.0010E-1	3.9815E-1	3.9624E-1	3.9438E-1	3.9254E-1
323.15	4.1028E-1	4.1008E-1	4.0921E-1	4.0813E-1	4.0602E-1	4.0396E-1	4.0196E-1	3.9999E-1	3.9807E-1	3.9619E-1
328.15	4.1452E-1	4.1431E-1	4.1341E-1	4.1229E-1	4.1010E-1	4.0798E-1	4.0590E-1	4.0388E-1	4.0190E-1	3.9996E-1
333.15	4.1892E-1	4.1870E-1	4.1776E-1	4.1660E-1	4.1434E-1	4.1213E-1	4.0999E-1	4.0790E-1	4.0586E-1	4.0386E-1
338.15	4.2347E-1	4.2325E-1	4.2227E-1	4.2107E-1	4.1872E-1	4.1643E-1	4.1421E-1	4.1205E-1	4.0995E-1	4.0789E-1
343.15	4.2819E-1	4.2796E-1	4.2694E-1	4.2569E-1	4.2325E-1	4.2088E-1	4.1858E-1	4.1635E-1	4.1417E-1	4.1205E-1
348.15	4.3307E-1	4.3283E-1	4.3177E-1	4.3047E-1	4.2793E-1	4.2547E-1	4.2309E-1	4.2077E-1	4.1853E-1	4.1634E-1
353.15	4.3810E-1	4.3785E-1	4.3675E-1	4.3539E-1	4.3275E-1	4.3020E-1	4.2773E-1	4.2533E-1	4.2301E-1	4.2075E-1
358.15	4.4330E-1	4.4304E-1	4.4189E-1	4.4048E-1	4.3773E-1	4.3508E-1	4.3251E-1	4.3003E-1	4.2762E-1	4.2529E-1
363.15	4.4866E-1	4.4839E-1	4.4719E-1	4.4572E-1	4.4285E-1	4.4010E-1	4.3743E-1	4.3486E-1	4.3237E-1	4.2995E-1
368.15	4.5419E-1	4.5391E-1	4.5265E-1	4.5112E-1	4.4813E-1	4.4526E-1	4.4250E-1	4.3982E-1	4.3724E-1	4.3474E-1
373.15	4.5989E-1	4.5959E-1	4.5828E-1	4.5667E-1	4.5356E-1	4.5057E-1	4.4770E-1	4.4492E-1	4.4224E-1	4.3965E-1
383.15	4.7147E-1	4.7114E-1	4.7004E-1	4.6828E-1	4.6489E-1	4.6165E-1	4.5853E-1	4.5553E-1	4.5264E-1	4.4986E-1
393.15	4.8406E-1	4.8249E-1	4.8249E-1	4.8057E-1	4.7686E-1	4.7333E-1	4.6994E-1	4.6670E-1	4.6358E-1	4.6057E-1
398.15	4.9663E-1	4.8898E-1	4.8898E-1	4.8697E-1	4.8310E-1	4.7940E-1	4.7587E-1	4.7249E-1	4.6925E-1	4.6613E-1
403.15	4.9740E-1	4.9567E-1	4.9567E-1	4.9356E-1	4.8950E-1	4.8564E-1	4.8196E-1	4.7844E-1	4.7506E-1	4.7181E-1
413.15	5.1154E-1	5.0963E-1	5.0963E-1	5.0731E-1	5.0285E-1	4.9862E-1	4.9460E-1	4.9077E-1	4.8710E-1	4.8359E-1
423.15	5.2654E-1	5.2443E-1	5.2443E-1	5.2186E-1	5.1694E-1	5.1230E-1	5.0790E-1	5.0372E-1	4.9973E-1	4.9593E-1
433.15	5.4248E-1	5.4012E-1	5.4012E-1	5.3727E-1	5.3184E-1	5.2673E-1	5.2190E-1	5.1733E-1	5.1298E-1	5.0884E-1

TABLE 5 (cont.) Debye Huckel limiting law slopes for osmotic coefficient  $A_\phi$ , units =  $(\text{kg/mol})^{-1/2}$ .

T/K	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
443.15		5.5944E-1	5.5681E-1	5.5363E-1	5.4760E-1	5.4195E-1	5.3664E-1	5.3162E-1	5.2688E-1	5.2237E-1
448.15		5.6833E-1	5.6555E-1	5.6219E-1	5.583E-1	5.4988E-1	5.4430E-1	5.3905E-1	5.3408E-1	5.2937E-1
453.15			5.7458E-1	5.7102E-1	5.6430E-1	5.5804E-1	5.5217E-1	5.4666E-1	5.4146E-1	5.3653E-1
463.15			5.9356E-1	5.8956E-1	5.8204E-1	5.7506E-1	5.6857E-1	5.6249E-1	5.5678E-1	5.5139E-1
473.15			6.1391E-1	6.0938E-1	6.0091E-1	5.9312E-1	5.8590E-1	5.7918E-1	5.7288E-1	5.6697E-1
498.15			6.7203E-1	6.6569E-1	6.5403E-1	6.4351E-1	6.3394E-1	6.2515E-1	6.1703E-1	6.0949E-1
523.15			7.4437E-1	7.3496E-1	7.1812E-1	7.0338E-1	6.9029E-1	6.7850E-1	6.6779E-1	6.5799E-1
523.15			7.4437E-1	7.3496E-1	7.1812E-1	7.0338E-1	6.9029E-1	6.7850E-1	6.6779E-1	6.5799E-1
548.15				8.2434E-1	7.9824E-1	7.7648E-1	7.5782E-1	7.4150E-1	7.2700E-1	7.1396E-1
573.15				9.4958E-1	9.0407E-1	8.6932E-1	8.4120E-1	8.162E-1	7.9732E-1	7.7954E-1
598.15					1.0579E+0	9.9455E-1	9.4852E-1	9.1244E-1	8.8283E-1	8.5777E-1
623.15					1.3378E+0	1.1821E+0	1.0955E+0	1.0356E+0	9.8991E-1	9.5320E-1
648.15	1.5485E+0	4.7984E+0	9.7122E+0	1.1768E+1	9.1917E+0	1.5354E+0	1.3186E+0	1.2052E+0	1.1293E+0	1.0728E+0
673.15	1.4357E+0	4.4535E+0	9.0673E+0	1.1140E+1	1.0247E+1	3.1276E+0	1.7264E+0	1.4600E+0	1.3200E+0	1.2276E+0
698.15	1.3349E+0	4.1445E+0	8.4840E+0	1.0543E+1	1.0431E+1	6.6669E+0	2.7163E+0	1.8879E+0	1.5968E+0	1.4352E+0
723.15	1.2443E+0	3.8667E+0	7.9544E+0	9.9805E+0	1.0343E+1	7.9392E+0	4.5104E+0	2.6430E+0	2.0148E+0	1.7212E+0
748.15	1.1626E+0	3.6159E+0	7.4722E+0	9.4535E+0	1.0130E+1	8.4973E+0	5.8882E+0	3.7121E+0	2.6204E+0	2.1122E+0
773.15	1.0888E+0	3.3888E+0	7.0320E+0	8.9611E+0	9.8550E+0	8.7363E+0	6.7216E+0	4.7291E+0	3.3660E+0	2.6118E+0
798.15	1.0217E+0	3.1824E+0	6.6290E+0	8.5018E+0	9.5486E+0	8.8003E+0	7.2228E+0	5.5019E+0	4.1066E+0	3.1789E+0
823.15	9.6066E-1	2.9943E+0	6.2592E+0	8.0734E+0	9.2281E+0	8.7587E+0	7.5162E+0	6.0518E+0	4.7381E+0	3.7436E+0
848.15	9.0493E-1	2.8224E+0	5.9190E+0	7.6740E+0	8.9039E+0	8.6501E+0	7.6726E+0	6.4325E+0	5.2381E+0	4.2513E+0
873.15	8.5390E-1	2.6649E+0	5.6055E+0	7.3013E+0	8.5822E+0	8.4982E+0	7.7345E+0	6.6878E+0	5.6198E+0	4.6798E+0
923.15	7.6400E-1	2.3869E+0	5.0479E+0	6.5284E+0	7.9605E+0	8.1203E+0	7.6775E+0	6.9401E+0	6.1077E+0	5.3043E+0
973.15	6.8758E-1	2.1502E+0	4.5685E+0	6.0399E+0	7.3796E+0	7.6976E+0	7.4785E+0	6.9721E+0	6.3373E+0	5.6775E+0
1023.15	6.2208E-1	1.9470E+0	4.1537E+0	5.5234E+0	6.8445E+0	7.2658E+0	7.2062E+0	6.8740E+0	6.3999E+0	5.8705E+0
1073.15	5.6551E-1	1.7713E+0	3.7923E+0	5.0681E+0	6.3550E+0	6.8428E+0	6.8983E+0	6.6988E+0	6.3540E+0	5.9373E+0
1123.15	5.1632E-1	1.6183E+0	3.4757E+0	4.6652E+0	5.9090E+0	6.4381E+0	6.5770E+0	6.4792E+0	6.2381E+0	5.9167E+0
1173.15	4.7327E-1	1.4843E+0	3.1968E+0	4.3073E+0	5.5032E+0	6.0559E+0	6.2553E+0	6.2355E+0	6.0776E+0	5.8360E+0
1223.15	4.3540E-1	1.3662E+0	2.9499E+0	3.9880E+0	5.1339E+0	5.6979E+0	5.9407E+0	5.9811E+0	5.8899E+0	5.7145E+0
1273.15	4.0189E-1	1.2617E+0	2.7303E+0	3.7022E+0	4.7977E+0	5.3643E+0	5.6378E+0	5.7245E+0	5.6866E+0	5.5661E+0

TABLE 5 (cont.) Debye Huckel limiting law slopes for osmotic coefficient  $A_\phi$ , units = (kg/mol)<sup>-1/2</sup>.

T/K	p/MPa									
	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
263.15	3.5818E-1	3.5520E-1	3.4806E-1	3.4130E-1	3.3486E-1	3.2874E-1	3.2293E-1	3.1743E-1	3.1222E-1	3.0730E-1
268.15	3.6104E-1	3.5805E-1	3.5086E-1	3.4402E-1	3.3752E-1	3.3134E-1	3.2548E-1	3.1993E-1	3.1469E-1	3.0975E-1
273.15	3.6374E-1	3.6073E-1	3.5347E-1	3.4656E-1	3.4000E-1	3.3377E-1	3.2787E-1	3.2228E-1	3.1701E-1	3.1203E-1
278.15	3.6639E-1	3.6335E-1	3.5602E-1	3.4905E-1	3.4243E-1	3.3616E-1	3.3021E-1	3.2459E-1	3.1928E-1	3.1427E-1
283.15	3.6907E-1	3.6600E-1	3.5859E-1	3.5156E-1	3.4488E-1	3.3856E-1	3.3258E-1	3.2692E-1	3.2158E-1	3.1654E-1
288.15	3.7183E-1	3.6871E-1	3.6121E-1	3.5411E-1	3.4739E-1	3.4102E-1	3.3500E-1	3.2931E-1	3.2393E-1	3.1886E-1
293.15	3.7468E-1	3.7151E-1	3.6392E-1	3.5675E-1	3.4997E-1	3.4356E-1	3.3750E-1	3.3177E-1	3.2636E-1	3.2125E-1
298.15	3.7764E-1	3.7442E-1	3.6672E-1	3.5947E-1	3.5263E-1	3.4617E-1	3.4007E-1	3.3430E-1	3.2886E-1	3.2372E-1
303.15	3.8073E-1	3.7745E-1	3.6963E-1	3.6229E-1	3.5538E-1	3.4887E-1	3.4272E-1	3.3691E-1	3.3143E-1	3.2625E-1
308.15	3.8394E-1	3.8059E-1	3.7264E-1	3.6520E-1	3.5822E-1	3.5164E-1	3.4545E-1	3.3960E-1	3.3407E-1	3.2886E-1
313.15	3.8728E-1	3.8386E-1	3.7576E-1	3.6822E-1	3.6115E-1	3.5451E-1	3.4825E-1	3.4236E-1	3.3679E-1	3.3154E-1
318.15	3.9075E-1	3.8725E-1	3.7899E-1	3.7133E-1	3.6417E-1	3.5745E-1	3.5114E-1	3.4519E-1	3.3957E-1	3.3427E-1
323.15	3.9434E-1	3.9076E-1	3.8233E-1	3.7453E-1	3.6727E-1	3.6048E-1	3.5409E-1	3.4809E-1	3.4242E-1	3.3707E-1
328.15	3.9807E-1	3.9439E-1	3.8577E-1	3.7784E-1	3.7047E-1	3.6358E-1	3.5712E-1	3.5105E-1	3.4533E-1	3.3993E-1
333.15	4.0191E-1	3.9814E-1	3.8932E-1	3.8123E-1	3.7375E-1	3.6676E-1	3.6023E-1	3.5408E-1	3.4830E-1	3.4285E-1
338.15	4.0589E-1	4.0201E-1	3.9298E-1	3.8473E-1	3.7711E-1	3.7002E-1	3.6340E-1	3.5718E-1	3.5133E-1	3.4581E-1
343.15	4.0999E-1	4.0600E-1	3.9674E-1	3.8831E-1	3.8055E-1	3.7335E-1	3.6663E-1	3.6034E-1	3.5441E-1	3.4884E-1
348.15	4.1421E-1	4.1010E-1	4.0060E-1	3.9198E-1	3.8408E-1	3.7676E-1	3.6994E-1	3.6355E-1	3.5756E-1	3.5191E-1
353.15	4.1855E-1	4.1432E-1	4.0456E-1	3.9575E-1	3.8768E-1	3.8024E-1	3.7331E-1	3.6683E-1	3.6075E-1	3.5503E-1
358.15	4.2302E-1	4.1865E-1	4.0862E-1	3.9960E-1	3.9137E-1	3.8378E-1	3.7674E-1	3.7016E-1	3.6400E-1	3.5820E-1
363.15	4.2760E-1	4.2310E-1	4.1278E-1	4.0354E-1	3.9513E-1	3.8740E-1	3.8023E-1	3.7355E-1	3.6730E-1	3.6142E-1
368.15	4.3231E-1	4.2766E-1	4.1704E-1	4.0756E-1	3.9897E-1	3.9108E-1	3.8379E-1	3.7700E-1	3.7065E-1	3.6468E-1
373.15	4.3714E-1	4.3233E-1	4.2140E-1	4.1167E-1	4.0288E-1	3.9483E-1	3.8740E-1	3.8050E-1	3.7404E-1	3.6799E-1
383.15	4.4716E-1	4.4203E-1	4.3040E-1	4.2015E-1	4.1093E-1	4.0254E-1	3.9481E-1	3.8766E-1	3.8099E-1	3.7474E-1
393.15	4.5768E-1	4.5217E-1	4.3979E-1	4.2895E-1	4.1927E-1	4.1049E-1	4.0245E-1	3.9502E-1	3.8812E-1	3.8166E-1
398.15	4.6312E-1	4.5742E-1	4.4463E-1	4.3348E-1	4.2355E-1	4.1457E-1	4.0636E-1	3.9878E-1	3.9175E-1	3.8518E-1
403.15	4.6899E-1	4.6278E-1	4.4957E-1	4.3809E-1	4.2790E-1	4.1871E-1	4.1032E-1	4.0259E-1	3.9543E-1	3.8874E-1
413.15	4.8022E-1	4.7386E-1	4.5974E-1	4.4756E-1	4.3681E-1	4.2717E-1	4.1840E-1	4.1035E-1	4.0291E-1	3.9599E-1
423.15	4.9228E-1	4.8542E-1	4.7029E-1	4.5735E-1	4.4600E-1	4.3587E-1	4.2670E-1	4.1831E-1	4.1057E-1	4.0338E-1
433.15	5.0489E-1	4.9747E-1	4.8125E-1	4.6748E-1	4.5548E-1	4.4482E-1	4.3521E-1	4.2645E-1	4.1840E-1	4.1093E-1

TABLE 5 (cont.) Debye Huckel limiting law slopes for osmotic coefficient  $A_{\phi}$ , units = (kg/mol)<sup>-1/2</sup>.

T/K	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
443.15	5.1807E-1	5.1005E-1	4.9261E-1	4.7794E-1	4.6524E-1	4.5401E-1	4.4393E-1	4.3478E-1	4.2639E-1	4.1863E-1
448.15	5.2489E-1	5.1653E-1	4.9845E-1	4.8530E-1	4.7022E-1	4.5870E-1	4.4838E-1	4.3901E-1	4.3044E-1	4.2253E-1
453.15	5.3186E-1	5.2316E-1	5.0440E-1	4.8874E-1	4.7528E-1	4.6345E-1	4.5287E-1	4.4329E-1	4.3454E-1	4.2647E-1
463.15	5.4629E-1	5.3683E-1	5.1661E-1	4.9989E-1	4.8561E-1	4.7312E-1	4.6201E-1	4.5199E-1	4.4285E-1	4.3445E-1
473.15	5.6139E-1	5.5110E-1	5.2928E-1	5.1140E-1	4.9623E-1	4.8305E-1	4.7136E-1	4.6086E-1	4.5132E-1	4.4257E-1
498.15	6.0244E-1	5.8961E-1	5.6302E-1	5.4178E-1	5.2410E-1	5.0894E-1	4.9566E-1	4.8384E-1	4.7318E-1	4.6347E-1
523.15	6.4894E-1	6.3272E-1	6.0002E-1	5.7464E-1	5.5393E-1	5.3643E-1	5.2130E-1	5.0795E-1	4.9602E-1	4.8522E-1
523.15	6.4894E-1	6.3272E-1	6.0002E-1	5.7464E-1	5.5393E-1	5.3643E-1	5.2130E-1	5.0795E-1	4.9602E-1	4.8522E-1
548.15	7.0213E-1	6.8132E-1	6.4071E-1	6.1021E-1	5.8585E-1	5.6561E-1	5.4831E-1	5.3322E-1	5.1984E-1	5.0781E-1
573.15	7.6372E-1	7.3559E-1	6.8564E-1	6.4877E-1	6.2003E-1	5.9656E-1	5.7677E-1	5.5968E-1	5.4465E-1	5.3125E-1
598.15	8.3610E-1	8.0004E-1	7.3544E-1	6.9066E-1	6.5666E-1	6.2941E-1	6.0673E-1	5.8737E-1	5.7049E-1	5.5555E-1
623.15	9.2261E-1	8.7369E-1	7.9089E-1	7.3625E-1	6.9595E-1	6.6427E-1	6.3828E-1	6.1633E-1	5.9737E-1	5.8071E-1
648.15	1.0281E+0	9.6019E-1	8.5289E-1	7.8596E-1	7.3812E-1	7.0127E-1	6.7149E-1	6.4662E-1	6.2534E-1	6.0678E-1
673.15	1.1596E+0	1.0530E+0	9.2244E-1	8.4022E-1	7.8339E-1	7.4054E-1	7.0644E-1	6.7829E-1	6.5441E-1	6.3375E-1
698.15	1.3274E+0	1.1867E+0	1.0007E+0	8.9946E-1	8.3197E-1	7.8219E-1	7.4319E-1	7.1137E-1	6.8463E-1	6.6165E-1
723.15	1.5456E+0	1.3367E+0	1.0888E+0	9.6413E-1	8.8405E-1	8.2633E-1	7.8181E-1	7.4590E-1	7.1600E-1	6.9050E-1
748.15	1.8294E+0	1.5193E+0	1.1881E+0	1.0346E+0	9.3980E-1	8.7304E-1	8.2234E-1	7.8191E-1	7.4854E-1	7.2029E-1
773.15	2.1867E+0	1.7592E+0	1.2997E+0	1.1113E+0	9.9935E-1	9.2235E-1	8.6478E-1	8.1939E-1	7.8225E-1	7.5103E-1
798.15	2.6073E+0	1.9972E+0	1.4242E+0	1.1943E+0	1.0628E+0	9.7428E-1	9.0914E-1	8.5833E-1	8.1712E-1	7.8270E-1
823.15	3.0614E+0	2.2879E+0	1.5621E+0	1.2839E+0	1.1300E+0	1.0288E+0	9.5537E-1	8.9871E-1	8.5311E-1	8.1528E-1
848.15	3.5105E+0	2.5997E+0	1.7124E+0	1.3799E+0	1.2011E+0	1.0859E+0	1.0034E+0	9.4047E-1	8.9020E-1	8.4874E-1
873.15	3.9244E+0	2.9181E+0	1.8735E+0	1.4820E+0	1.2759E+0	1.1454E+0	1.0532E+0	9.8354E-1	9.2831E-1	8.8303E-1
923.15	4.5945E+0	3.5195E+0	2.2171E+0	1.7020E+0	1.4355E+0	1.2711E+0	1.1576E+0	1.0733E+0	1.0073E+0	9.5386E-1
973.15	5.0540E+0	4.0184E+0	2.5665E+0	1.9362E+0	1.6059E+0	1.4044E+0	1.2674E+0	1.1671E+0	1.0895E+0	1.0272E+0
1023.15	5.3411E+0	4.3959E+0	2.8963E+0	2.1742E+0	1.7830E+0	1.5432E+0	1.3813E+0	1.2640E+0	1.1741E+0	1.1025E+0
1073.15	5.4977E+0	4.6821E+0	3.1887E+0	2.4052E+0	1.9615E+0	1.6849E+0	1.4979E+0	1.3629E+0	1.2603E+0	1.1791E+0
1123.15	5.5581E+0	4.8350E+0	3.4350E+0	2.6200E+0	2.1359E+0	1.8265E+0	1.6154E+0	1.4629E+0	1.3473E+0	1.2562E+0
1173.15	5.5484E+0	4.9329E+0	3.6337E+0	2.8125E+0	2.3011E+0	1.9650E+0	1.7320E+0	1.5626E+0	1.4342E+0	1.3333E+0
1223.15	5.4883E+0	4.9721E+0	3.7871E+0	2.9794E+0	2.4533E+0	2.0973E+0	1.8457E+0	1.6610E+0	1.5204E+0	1.4098E+0
1273.15	5.3924E+0	4.9556E+0	3.8997E+0	3.1197E+0	2.5897E+0	2.2208E+0	1.9548E+0	1.7567E+0	1.6048E+0	1.4851E+0



Table 6. Debye Huckel limiting law slopes for apparent molar enthalpy  $A_H/RT$ , units =  $(\text{kg/mol})^{-1/2}$ .

T/K	p/MPa									
	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
263.15	6.0434E-1	6.0519E-1	6.0878E-1	6.1285E-1	6.1973E-1	6.2507E-1	6.2905E-1	6.3182E-1	6.3353E-1	6.3431E-1
268.15	5.8963E-1	5.8987E-1	5.9087E-1	5.9194E-1	5.9353E-1	5.9444E-1	5.9474E-1	5.9449E-1	5.9375E-1	5.9257E-1
273.15	6.0031E-1	6.0013E-1	5.9934E-1	5.9832E-1	5.9619E-1	5.9394E-1	5.9157E-1	5.8909E-1	5.8650E-1	5.8382E-1
278.15	6.2663E-1	6.2615E-1	6.2405E-1	6.2150E-1	6.1659E-1	6.1193E-1	6.0749E-1	6.0324E-1	5.9915E-1	5.9521E-1
283.15	6.6281E-1	6.6210E-1	6.5899E-1	6.5523E-1	6.4813E-1	6.4153E-1	6.3537E-1	6.2962E-1	6.2422E-1	6.1915E-1
288.15	7.0535E-1	7.0445E-1	7.0051E-1	6.9576E-1	6.8682E-1	6.7856E-1	6.7092E-1	6.6383E-1	6.5724E-1	6.5110E-1
293.15	7.5213E-1	7.5106E-1	7.4641E-1	7.4080E-1	7.3024E-1	7.2050E-1	7.1150E-1	7.0317E-1	6.9544E-1	6.8827E-1
298.15	8.0185E-1	8.0063E-1	7.9532E-1	7.8893E-1	7.7689E-1	7.6577E-1	7.5549E-1	7.4597E-1	7.3715E-1	7.2896E-1
303.15	8.5370E-1	8.5234E-1	8.4642E-1	8.3928E-1	8.2583E-1	8.1339E-1	8.0187E-1	7.9119E-1	7.8128E-1	7.7207E-1
308.15	9.0720E-1	9.0571E-1	8.9919E-1	8.9133E-1	8.7650E-1	8.6275E-1	8.5001E-1	8.3818E-1	8.2718E-1	8.1694E-1
313.15	9.6209E-1	9.6046E-1	9.5335E-1	9.4477E-1	9.2854E-1	9.1350E-1	8.9952E-1	8.8652E-1	8.7442E-1	8.6314E-1
318.15	1.0182E+0	1.0164E+0	1.0087E+0	9.9940E-1	9.8177E-1	9.6540E-1	9.5017E-1	9.3598E-1	9.2275E-1	9.1040E-1
323.15	1.0755E+0	1.0736E+0	1.0652E+0	1.0552E+0	1.0361E+0	1.0183E+0	1.0018E+0	9.8640E-1	9.7201E-1	9.5856E-1
328.15	1.1340E+0	1.1319E+0	1.1229E+0	1.1120E+0	1.0914E+0	1.0722E+0	1.0544E+0	1.0377E+0	1.0221E+0	1.0075E+0
333.15	1.1936E+0	1.1914E+0	1.1817E+0	1.1700E+0	1.1478E+0	1.1271E+0	1.1079E+0	1.0899E+0	1.0731E+0	1.0573E+0
338.15	1.2545E+0	1.2521E+0	1.2417E+0	1.2291E+0	1.2052E+0	1.1830E+0	1.1623E+0	1.1429E+0	1.1248E+0	1.1078E+0
343.15	1.3168E+0	1.3142E+0	1.3030E+0	1.2895E+0	1.2638E+0	1.2400E+0	1.2177E+0	1.1969E+0	1.1774E+0	1.1591E+0
348.15	1.3805E+0	1.3777E+0	1.3657E+0	1.3512E+0	1.3236E+0	1.2980E+0	1.2741E+0	1.2517E+0	1.2308E+0	1.2112E+0
353.15	1.4458E+0	1.4428E+0	1.4299E+0	1.4143E+0	1.3847E+0	1.3572E+0	1.3316E+0	1.3076E+0	1.2852E+0	1.2641E+0
358.15	1.5128E+0	1.5096E+0	1.4957E+0	1.4789E+0	1.4472E+0	1.4177E+0	1.3902E+0	1.3646E+0	1.3405E+0	1.3180E+0
363.15	1.5816E+0	1.5782E+0	1.5633E+0	1.5452E+0	1.5112E+0	1.4796E+0	1.4501E+0	1.4226E+0	1.3969E+0	1.3728E+0
368.15	1.6525E+0	1.6488E+0	1.6327E+0	1.6134E+0	1.5768E+0	1.5429E+0	1.5114E+0	1.4820E+0	1.4544E+0	1.4286E+0
373.15	1.7255E+0	1.7215E+0	1.7042E+0	1.6834E+0	1.6442E+0	1.6079E+0	1.5741E+0	1.5426E+0	1.5132E+0	1.4856E+0
383.15	1.8742E+0	1.8742E+0	1.8542E+0	1.8301E+0	1.7849E+0	1.7430E+0	1.7043E+0	1.6682E+0	1.6346E+0	1.6032E+0
393.15	2.0378E+0	2.0378E+0	2.0146E+0	1.9867E+0	1.9344E+0	1.8862E+0	1.8417E+0	1.8004E+0	1.7620E+0	1.7262E+0
398.15	2.1243E+0	2.1243E+0	2.0993E+0	2.0692E+0	2.0129E+0	1.9611E+0	1.9134E+0	1.8692E+0	1.8282E+0	1.7899E+0
403.15	2.2144E+0	2.2144E+0	2.1873E+0	2.1548E+0	2.0942E+0	2.0386E+0	1.9874E+0	1.9401E+0	1.8962E+0	1.8554E+0
413.15	2.4061E+0	2.4061E+0	2.3744E+0	2.3365E+0	2.2660E+0	2.2016E+0	2.1427E+0	2.0884E+0	2.0382E+0	1.9917E+0
423.15	2.6159E+0	2.6159E+0	2.5785E+0	2.5340E+0	2.4517E+0	2.3771E+0	2.3090E+0	2.2466E+0	2.1892E+0	2.1361E+0
433.15	2.8469E+0	2.8469E+0	2.8027E+0	2.7502E+0	2.6537E+0	2.5668E+0	2.4880E+0	2.4161E+0	2.3502E+0	2.2896E+0

Table 6 (cont.) Debye Huckel limiting law slopes for apparent molar enthalpy  $A_H/RT$ , units =  $(\text{kg/mol})^{-1/2}$ .

T/K	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
443.15		3.1032E+0	3.0506E+0	2.9885E+0	2.8747E+0	2.7731E+0	2.6815E+0	2.5985E+0	2.5228E+0	2.4534E+0
448.15		3.2425E+0	3.1849E+0	3.1171E+0	2.9934E+0	2.8833E+0	2.7844E+0	2.6951E+0	2.6139E+0	2.5396E+0
453.15			3.3270E+0	3.2528E+0	3.1181E+0	2.9986E+0	2.8919E+0	2.7957E+0	2.7085E+0	2.6289E+0
463.15			3.6375E+0	3.5483E+0	3.3877E+0	3.2467E+0	3.1217E+0	3.0098E+0	2.9091E+0	2.8177E+0
473.15			3.9896E+0	3.8815E+0	3.6886E+0	3.5211E+0	3.3740E+0	3.2435E+0	3.1267E+0	3.0215E+0
498.15			5.1217E+0	4.9383E+0	4.6214E+0	4.3561E+0	4.1298E+0	3.9340E+0	3.7624E+0	3.6106E+0
523.15			6.8448E+0	6.5041E+0	5.9435E+0	5.4987E+0	5.1351E+0	4.8310E+0	4.5719E+0	4.3480E+0
523.15			6.8448E+0	6.5041E+0	5.9435E+0	5.4987E+0	5.1351E+0	4.8310E+0	4.5719E+0	4.3480E+0
548.15				9.0708E+0	7.9595E+0	7.1516E+0	6.5317E+0	6.0378E+0	5.6329E+0	5.2936E+0
573.15				1.4086E+1	1.1391E+1	9.7299E+0	8.5812E+0	7.7301E+0	7.0691E+0	6.5380E+0
598.15					1.8500E+1	1.4239E+1	1.1821E+1	1.0229E+1	9.0877E+0	8.2222E+0
623.15					4.2640E+1	2.3877E+1	1.7541E+1	1.4183E+1	1.2058E+1	1.0576E+1
648.15	-1.2371E+1	-3.7832E+1	-7.0366E+1	-6.6208E+1	2.3603E+2	5.6179E+1	2.9590E+1	2.1053E+1	1.6685E+1	1.3989E+1
673.15	-1.1470E+1	-3.5117E+1	-6.5993E+1	-6.6081E+1	4.6248E+1	4.6011E+2	6.3326E+1	3.4503E+1	2.4363E+1	1.9125E+1
698.15	-1.0665E+1	-3.2689E+1	-6.2030E+1	-6.4827E+1	1.0611E+0	2.1827E+2	1.7022E+2	6.3027E+1	3.7624E+1	2.7029E+1
723.15	-9.9413E+0	-3.0508E+1	-5.8416E+1	-6.3036E+1	-1.9102E+1	9.3427E+1	1.9867E+2	1.1029E+2	5.8864E+1	3.8758E+1
748.15	-9.2892E+0	-2.8541E+1	-5.5107E+1	-6.0987E+1	-3.0010E+1	4.3570E+1	1.2731E+2	1.3236E+2	8.3204E+1	5.3639E+1
773.15	-8.6992E+0	-2.6759E+1	-5.2067E+1	-5.8826E+1	-3.6421E+1	1.6830E+1	7.9165E+1	1.1134E+2	9.5050E+1	6.7292E+1
798.15	-8.1637E+0	-2.5140E+1	-4.9267E+1	-5.6636E+1	-4.0303E+1	3.7713E-1	4.8817E+1	8.3291E+1	8.8785E+1	7.3766E+1
823.15	-7.6762E+0	-2.3665E+1	-4.6682E+1	-5.4465E+1	-4.2630E+1	-1.0535E+1	2.8452E+1	6.0175E+1	7.4417E+1	7.1442E+1
848.15	-7.2311E+0	-2.2316E+1	-4.4290E+1	-5.2344E+1	-4.3942E+1	-1.8099E+1	1.4051E+1	4.2314E+1	5.9380E+1	6.3713E+1
873.15	-6.8237E+0	-2.1079E+1	-4.2072E+1	-5.0288E+1	-4.4566E+1	-2.3478E+1	3.4836E+0	2.8495E+1	4.6005E+1	5.4157E+1
923.15	-6.1057E+0	-1.8895E+1	-3.8097E+1	-4.6411E+1	-4.4515E+1	-3.0155E+1	-1.0569E+1	9.0604E+0	2.5118E+1	3.5884E+1
973.15	-5.4954E+0	-1.7034E+1	-3.4647E+1	-4.2863E+1	-4.3466E+1	-3.3581E+1	-1.8983E+1	-3.4424E+0	1.0441E+1	2.1221E+1
1023.15	-4.9722E+0	-1.5435E+1	-3.1635E+1	-3.9640E+1	-4.1910E+1	-3.5156E+1	-2.4130E+1	-1.1734E+1	4.8257E-2	1.0013E+1
1073.15	-4.5203E+0	-1.4051E+1	-2.8992E+1	-3.6721E+1	-4.0111E+1	-3.5618E+1	-2.7244E+1	-1.7310E+1	-7.3852E+0	1.5245E+0
1123.15	-4.1273E+0	-1.2844E+1	-2.6660E+1	-3.4080E+1	-3.8218E+1	-3.5394E+1	-2.9037E+1	-2.1057E+1	-1.2728E+1	-4.8956E+0
1173.15	-3.7834E+0	-1.1787E+1	-2.4594E+1	-3.1689E+1	-3.6318E+1	-3.4744E+1	-2.9949E+1	-2.3535E+1	-1.6561E+1	-9.7443E+0
1223.15	-3.4808E+0	-1.0854E+1	-2.2755E+1	-2.9524E+1	-3.4461E+1	-3.3832E+1	-3.0261E+1	-2.5115E+1	-1.9288E+1	-1.3392E+1
1273.15	-3.2131E+0	-1.0028E+1	-2.1111E+1	-2.7559E+1	-3.2673E+1	-3.2765E+1	-3.0162E+1	-2.6050E+1	-2.1192E+1	-1.6116E+1

Table 6. (cont.) Debye Huckel limiting law slopes for apparent molar enthalpy  $A_H/RT$ , units = (kg/mol)<sup>-1/2</sup>.

T/K	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
263.15	6.3428E-1	6.3229E-1	6.2034E-1	6.0483E-1	5.8999E-1	5.7734E-1	5.6706E-1	5.5879E-1	5.5209E-1	5.4653E-1
268.15	5.9101E-1	5.8696E-1	5.7359E-1	5.5892E-1	5.4527E-1	5.3342E-1	5.2339E-1	5.1487E-1	5.0747E-1	5.0086E-1
273.15	5.8106E-1	5.7535E-1	5.6068E-1	5.4664E-1	5.3409E-1	5.2319E-1	5.1376E-1	5.0545E-1	4.9793E-1	4.9093E-1
278.15	5.9140E-1	5.8415E-1	5.6783E-1	5.5383E-1	5.4189E-1	5.3166E-1	5.2273E-1	5.1469E-1	5.0723E-1	5.0009E-1
283.15	6.1437E-1	6.0557E-1	5.8714E-1	5.7250E-1	5.6056E-1	5.5053E-1	5.4179E-1	5.3388E-1	5.2642E-1	5.1919E-1
288.15	6.4537E-1	6.3499E-1	6.1401E-1	5.9809E-1	5.8553E-1	5.7520E-1	5.6629E-1	5.5833E-1	5.5062E-1	5.4320E-1
293.15	6.8160E-1	6.6959E-1	6.4567E-1	6.2794E-1	6.1424E-1	6.0314E-1	5.9368E-1	5.8519E-1	5.7722E-1	5.6947E-1
298.15	7.2134E-1	7.0764E-1	6.8048E-1	6.6051E-1	6.4522E-1	6.3295E-1	6.2260E-1	6.1340E-1	6.0485E-1	5.9661E-1
303.15	7.6350E-1	7.4806E-1	7.1741E-1	6.9486E-1	6.7762E-1	6.6386E-1	6.5232E-1	6.4217E-1	6.3283E-1	6.2393E-1
308.15	8.0740E-1	7.9017E-1	7.5582E-1	7.3043E-1	7.1097E-1	6.9544E-1	6.8247E-1	6.7115E-1	6.6084E-1	6.5113E-1
313.15	8.5260E-1	8.3354E-1	7.9532E-1	7.6688E-1	7.4497E-1	7.2746E-1	7.1286E-1	7.0020E-1	6.8877E-1	6.7811E-1
318.15	8.9884E-1	8.7790E-1	8.3566E-1	8.0399E-1	7.7946E-1	7.5979E-1	7.4342E-1	7.2926E-1	7.1658E-1	7.0486E-1
323.15	9.4596E-1	9.2306E-1	8.7667E-1	8.4163E-1	8.1435E-1	7.9238E-1	7.7409E-1	7.5832E-1	7.4428E-1	7.3141E-1
328.15	9.9386E-1	9.6895E-1	9.1825E-1	8.7973E-1	8.4956E-1	8.2519E-1	8.0488E-1	7.8741E-1	7.7191E-1	7.5781E-1
333.15	1.0425E+0	1.0155E+0	9.6036E-1	9.1822E-1	8.8507E-1	8.5821E-1	8.3579E-1	8.1653E-1	7.9951E-1	7.8410E-1
338.15	1.0918E+0	1.0627E+0	1.0029E+0	9.5709E-1	9.2086E-1	8.9142E-1	8.6682E-1	8.4570E-1	8.2710E-1	8.1032E-1
343.15	1.1419E+0	1.1105E+0	1.0460E+0	9.9632E-1	9.5692E-1	9.2483E-1	8.9799E-1	8.7496E-1	8.5471E-1	8.3652E-1
348.15	1.1927E+0	1.1590E+0	1.0896E+0	1.0359E+0	9.9326E-1	9.5844E-1	9.2929E-1	9.0430E-1	8.8237E-1	8.6272E-1
353.15	1.2443E+0	1.2081E+0	1.1336E+0	1.0759E+0	1.0299E+0	9.9226E-1	9.6075E-1	9.3374E-1	9.1008E-1	8.8894E-1
358.15	1.2968E+0	1.2580E+0	1.1782E+0	1.1162E+0	1.0688E+0	1.0263E+0	9.9238E-1	9.6331E-1	9.3788E-1	9.1521E-1
363.15	1.3501E+0	1.3087E+0	1.2232E+0	1.1569E+0	1.1040E+0	1.0606E+0	1.0242E+0	9.9300E-1	9.6577E-1	9.4154E-1
368.15	1.4044E+0	1.3601E+0	1.2689E+0	1.1981E+0	1.1415E+0	1.0951E+0	1.0561E+0	1.0228E+0	9.9375E-1	9.6793E-1
373.15	1.4597E+0	1.4125E+0	1.3152E+0	1.2397E+0	1.1793E+0	1.1298E+0	1.0883E+0	1.0528E+0	1.0219E+0	9.9441E-1
383.15	1.5737E+0	1.5200E+0	1.4097E+0	1.3243E+0	1.2560E+0	1.2001E+0	1.1533E+0	1.1132E+0	1.0784E+0	1.0476E+0
393.15	1.6926E+0	1.6317E+0	1.5071E+0	1.4109E+0	1.3343E+0	1.2716E+0	1.2191E+0	1.1743E+0	1.1355E+0	1.1012E+0
398.15	1.7542E+0	1.6893E+0	1.5570E+0	1.4551E+0	1.3740E+0	1.3078E+0	1.2524E+0	1.2052E+0	1.1642E+0	1.1282E+0
403.15	1.8173E+0	1.7482E+0	1.6077E+0	1.4999E+0	1.4142E+0	1.3443E+0	1.2859E+0	1.2362E+0	1.1932E+0	1.1553E+0
413.15	1.9484E+0	1.8702E+0	1.7120E+0	1.5915E+0	1.4961E+0	1.4185E+0	1.3538E+0	1.2989E+0	1.2515E+0	1.2099E+0
423.15	2.0868E+0	1.9982E+0	1.8204E+0	1.6859E+0	1.5800E+0	1.4942E+0	1.4229E+0	1.3625E+0	1.3105E+0	1.2650E+0
433.15	2.2355E+0	2.1331E+0	1.9333E+0	1.7835E+0	1.6662E+0	1.5716E+0	1.4932E+0	1.4271E+0	1.3702E+0	1.3206E+0

Table 6. (cont.) Debye Huckel limiting law slopes for apparent molar enthalpy  $A_H/RT$ , units = (kg/mol.)<sup>-1/2</sup>.

T/K	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
443.15	2.3895E+0	2.2757E+0	2.0512E+0	1.8845E+0	1.7549E+0	1.6508E+0	1.5650E+0	1.4927E+0	1.4308E+0	1.3769E+0
448.15	2.4714E+0	2.3501E+0	2.1122E+0	1.9364E+0	1.8003E+0	1.6912E+0	1.6014E+0	1.5259E+0	1.4614E+0	1.4053E+0
453.15	2.5560E+0	2.4268E+0	2.1747E+0	1.9894E+0	1.8463E+0	1.7320E+0	1.6382E+0	1.5595E+0	1.4922E+0	1.4339E+0
463.15	2.7343E+0	2.5875E+0	2.3042E+0	2.0983E+0	1.9407E+0	1.8155E+0	1.7131E+0	1.6275E+0	1.5546E+0	1.4916E+0
473.15	2.9259E+0	2.7589E+0	2.4403E+0	2.2118E+0	2.0382E+0	1.9012E+0	1.7897E+0	1.6968E+0	1.6180E+0	1.5500E+0
498.15	3.4750E+0	3.2425E+0	2.8141E+0	2.5175E+0	2.2975E+0	2.1267E+0	1.9896E+0	1.8765E+0	1.7813E+0	1.6999E+0
523.15	4.1520E+0	3.8243E+0	3.2448E+0	2.8599E+0	2.5822E+0	2.3705E+0	2.2029E+0	2.0663E+0	1.9524E+0	1.8557E+0
523.15	4.1520E+0	3.8243E+0	3.2448E+0	2.8599E+0	2.5822E+0	2.3705E+0	2.2029E+0	2.0663E+0	1.9524E+0	1.8557E+0
548.15	5.0044E+0	4.5352E+0	3.7458E+0	3.2461E+0	2.8962E+0	2.6352E+0	2.4316E+0	2.2677E+0	2.1323E+0	2.0183E+0
573.15	6.1001E+0	5.4167E+0	4.3326E+0	3.6835E+0	3.2440E+0	2.9234E+0	2.6775E+0	2.4819E+0	2.3220E+0	2.1884E+0
598.15	7.5396E+0	6.5244E+0	5.0235E+0	4.1801E+0	3.6297E+0	3.2377E+0	2.9422E+0	2.7101E+0	2.5223E+0	2.3667E+0
623.15	9.4748E+0	7.9339E+0	5.8391E+0	4.7442E+0	4.0572E+0	3.5803E+0	3.2270E+0	2.9532E+0	2.7339E+0	2.5537E+0
648.15	1.2141E+1	9.7481E+0	6.8025E+0	5.3833E+0	4.5299E+0	3.9527E+0	3.5329E+0	3.2118E+0	2.9572E+0	2.7497E+0
673.15	1.5901E+1	1.2104E+1	7.9380E+0	6.1043E+0	5.0500E+0	4.3561E+0	3.8603E+0	3.4861E+0	3.1924E+0	2.9550E+0
698.15	2.1270E+1	1.5174E+1	9.2701E+0	6.9126E+0	5.6188E+0	4.7902E+0	4.2090E+0	3.7760E+0	3.4394E+0	3.1693E+0
723.15	2.8775E+1	1.9128E+1	1.0820E+1	7.8111E+0	6.2357E+0	5.2543E+0	4.5780E+0	4.0805E+0	3.6974E+0	3.3922E+0
748.15	3.8357E+1	2.4022E+1	1.2598E+1	8.7996E+0	6.8987E+0	5.7460E+0	4.9656E+0	4.3984E+0	3.9655E+0	3.6230E+0
773.15	4.8549E+1	2.9607E+1	1.4594E+1	9.8733E+0	7.6037E+0	6.2621E+0	5.3691E+0	4.7277E+0	4.2422E+0	3.8605E+0
798.15	5.6650E+1	3.5221E+1	1.6760E+1	1.1021E+1	8.3448E+0	6.7986E+0	5.7855E+0	5.0659E+0	4.5256E+0	4.1033E+0
823.15	6.0292E+1	3.9977E+1	1.9001E+1	1.2224E+1	9.1139E+0	7.3502E+0	6.2110E+0	5.4103E+0	4.8135E+0	4.3497E+0
848.15	5.9081E+1	4.3109E+1	2.1182E+1	1.3453E+1	9.9010E+0	7.9113E+0	6.6418E+0	5.7577E+0	5.1036E+0	4.5979E+0
873.15	5.4453E+1	4.4233E+1	2.3150E+1	1.4671E+1	1.0693E+1	8.4757E+0	7.0735E+0	6.1052E+0	5.3934E+0	4.8458E+0
923.15	4.1365E+1	4.1147E+1	2.5930E+1	1.6890E+1	1.2232E+1	9.5865E+0	7.9233E+0	6.7880E+0	5.9623E+0	5.3326E+0
973.15	2.8487E+1	3.4099E+1	2.6731E+1	1.8526E+1	1.3591E+1	1.0623E+1	8.7283E+0	7.4362E+0	6.5026E+0	5.7955E+0
1023.15	1.7636E+1	2.6118E+1	2.5642E+1	1.9333E+1	1.4627E+1	1.1519E+1	9.4558E+0	8.0306E+0	7.0001E+0	6.2225E+0
1073.15	8.8860E+0	1.8571E+1	2.3193E+1	1.9247E+1	1.5223E+1	1.2208E+1	1.0073E+1	8.5539E+0	7.4441E+0	6.6054E+0
1123.15	1.9378E+0	1.1908E+1	1.9979E+1	1.8371E+1	1.5325E+1	1.2630E+1	1.0544E+1	8.9886E+0	7.8255E+0	6.9387E+0
1173.15	-3.5396E+0	6.2046E+0	1.6463E+1	1.6895E+1	1.4946E+1	1.2748E+1	1.0838E+1	9.3157E+0	8.1348E+0	7.2177E+0
1223.15	-7.8351E+0	1.4053E+0	1.2934E+1	1.5029E+1	1.4154E+1	1.2553E+1	1.0930E+1	9.5165E+0	8.3613E+0	7.4372E+0
1273.15	-1.1185E+1	-2.5901E+0	9.5596E+0	1.2948E+1	1.3044E+1	1.2070E+1	1.0909E+1	9.5750E+0	8.4937E+0	7.5912E+0

Table 7. Debye Huckel limiting law slopes for apparent molar volume  $A_V$ , units =  $\text{cm}^3 \text{ mol}^{-3/2}$ .

T/K	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
263.15	1.4769E+0	1.4747E+0	1.4650E+0	1.4533E+0	1.4310E+0	1.4099E+0	1.3897E+0	1.3704E+0	1.3520E+0	1.3343E+0
268.15	1.4801E+0	1.4784E+0	1.4708E+0	1.4614E+0	1.4434E+0	1.4261E+0	1.4094E+0	1.3932E+0	1.3774E+0	1.3620E+0
273.15	1.5066E+0	1.5050E+0	1.4980E+0	1.4894E+0	1.4727E+0	1.4566E+0	1.4410E+0	1.4257E+0	1.4108E+0	1.3961E+0
278.15	1.5498E+0	1.5481E+0	1.5407E+0	1.5318E+0	1.5145E+0	1.4978E+0	1.4817E+0	1.4660E+0	1.4506E+0	1.4355E+0
283.15	1.6057E+0	1.6038E+0	1.5955E+0	1.5855E+0	1.5662E+0	1.5477E+0	1.5300E+0	1.5128E+0	1.4961E+0	1.4798E+0
288.15	1.6720E+0	1.6698E+0	1.6602E+0	1.6486E+0	1.6263E+0	1.6051E+0	1.5849E+0	1.5655E+0	1.5468E+0	1.5287E+0
293.15	1.7472E+0	1.7446E+0	1.7334E+0	1.7198E+0	1.6938E+0	1.6693E+0	1.6460E+0	1.6238E+0	1.6026E+0	1.5821E+0
298.15	1.8305E+0	1.8275E+0	1.8143E+0	1.7984E+0	1.7682E+0	1.7398E+0	1.7130E+0	1.6875E+0	1.6633E+0	1.6401E+0
303.15	1.9214E+0	1.9179E+0	1.9027E+0	1.8842E+0	1.8492E+0	1.8165E+0	1.7857E+0	1.7566E+0	1.7290E+0	1.7028E+0
308.15	2.0198E+0	2.0158E+0	1.9982E+0	1.9769E+0	1.9367E+0	1.8992E+0	1.8641E+0	1.8310E+0	1.7998E+0	1.7702E+0
313.15	2.1256E+0	2.1210E+0	2.1008E+0	2.0766E+0	2.0307E+0	1.9881E+0	1.9483E+0	1.9109E+0	1.8757E+0	1.8424E+0
318.15	2.2389E+0	2.2337E+0	2.2108E+0	2.1833E+0	2.1314E+0	2.0833E+0	2.0384E+0	1.9969E+0	1.9569E+0	1.9197E+0
323.15	2.3601E+0	2.3542E+0	2.3284E+0	2.2974E+0	2.2390E+0	2.1849E+0	2.1346E+0	2.0875E+0	2.0435E+0	2.0021E+0
328.15	2.4894E+0	2.4828E+0	2.4539E+0	2.4191E+0	2.3538E+0	2.2933E+0	2.2371E+0	2.1848E+0	2.1358E+0	2.0899E+0
333.15	2.6273E+0	2.6199E+0	2.5876E+0	2.5489E+0	2.4760E+0	2.4087E+0	2.3463E+0	2.2882E+0	2.2340E+0	2.1833E+0
338.15	2.7743E+0	2.7660E+0	2.7302E+0	2.6871E+0	2.6061E+0	2.5314E+0	2.4623E+0	2.3982E+0	2.3384E+0	2.2825E+0
343.15	2.9309E+0	2.9218E+0	2.8820E+0	2.8342E+0	2.7445E+0	2.6620E+0	2.5857E+0	2.5150E+0	2.4492E+0	2.3878E+0
348.15	3.0979E+0	3.0878E+0	3.0437E+0	2.9909E+0	2.8918E+0	2.8008E+0	2.7168E+0	2.6390E+0	2.5668E+0	2.4995E+0
353.15	3.2759E+0	3.2647E+0	3.2160E+0	3.1577E+0	3.0485E+0	2.9483E+0	2.8560E+0	2.7707E+0	2.6916E+0	2.6180E+0
358.15	3.4657E+0	3.4534E+0	3.3997E+0	3.3354E+0	3.2152E+0	3.1051E+0	3.0039E+0	2.9104E+0	2.8238E+0	2.7434E+0
363.15	3.6683E+0	3.6546E+0	3.5955E+0	3.5247E+0	3.3926E+0	3.2718E+0	3.1608E+0	3.0586E+0	2.9640E+0	2.8764E+0
368.15	3.8845E+0	3.8695E+0	3.8044E+0	3.7266E+0	3.5815E+0	3.4490E+0	3.3276E+0	3.2158E+0	3.1127E+0	3.0171E+0
373.15	4.1156E+0	4.0990E+0	4.0274E+0	3.9418E+0	3.7826E+0	3.6375E+0	3.5046E+0	3.3827E+0	3.2702E+0	3.1662E+0
383.15		4.6069E+0	4.5203E+0	4.4169E+0	4.2252E+0	4.0513E+0	3.8927E+0	3.7476E+0	3.6142E+0	3.4913E+0
393.15		5.1892E+0	5.0843E+0	4.9595E+0	4.7289E+0	4.5205E+0	4.3314E+0	4.1589E+0	4.0010E+0	3.8559E+0
398.15		5.5124E+0	5.3969E+0	5.2597E+0	5.0066E+0	4.7785E+0	4.5719E+0	4.3839E+0	4.2122E+0	4.0546E+0
402.15		5.8595E+0	5.7323E+0	5.5813E+0	5.3034E+0	5.0537E+0	4.8280E+0	4.6231E+0	4.4362E+0	4.2652E+0
413.15		6.6345E+0	6.4797E+0	6.2965E+0	5.9609E+0	5.6611E+0	5.3915E+0	5.1479E+0	4.9267E+0	4.7250E+0
423.15		7.5351E+0	7.3458E+0	7.1226E+0	6.7161E+0	6.3551E+0	6.0326E+0	5.7425E+0	5.4804E+0	5.2423E+0
433.15		8.5874E+0	8.3547E+0	8.0315E+0	7.5869E+0	7.1509E+0	6.7638E+0	6.4177E+0	6.1066E+0	5.8253E+0

Table 7 (cont.) Debye Huckel limiting law slopes for apparent molar volume  $V_{\phi}$ , units =  $\text{cm}^3 \text{kg}^{-1/2} \text{mol}^{-3/2}$ .

T/K	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
443.15		9.8249E+0	9.5370E+0	9.2005E+0	8.5955E+0	8.0667E+0	7.6006E+0	7.1865E+0	6.8164E+0	6.4835E+0
448.15		1.0526E+1	1.0205E+1	9.8306E+0	9.1599E+0	8.5765E+0	8.0642E+0	7.6108E+0	7.2066E+0	6.8442E+0
453.15			1.0932E+1	1.0514E+1	9.7698E+0	9.1251E+0	8.5615E+0	8.0645E+0	7.6229E+0	7.2280E+0
463.15			1.2589E+1	1.2067E+1	1.1144E+1	1.0354E+1	9.6694E+0	9.0704E+0	8.5420E+0	8.0723E+0
473.15			1.4577E+1	1.3917E+1	1.2764E+1	1.1788E+1	1.0952E+1	1.0227E+1	9.5923E+0	9.0321E+0
498.15			2.1654E+1	2.0408E+1	1.8303E+1	1.6592E+1	1.5173E+1	1.3977E+1	1.2954E+1	1.2069E+1
523.15			3.4107E+1	3.1490E+1	2.7305E+1	2.4101E+1	2.1566E+1	1.9508E+1	1.7804E+1	1.6369E+1
548.15			3.4107E+1	3.1490E+1	2.7305E+1	2.4101E+1	2.1566E+1	1.9508E+1	1.7804E+1	1.6369E+1
573.15			5.2625E+1	4.3147E+1	3.6559E+1	3.1702E+1	2.7969E+1	2.5007E+1	2.2600E+1	2.0600E+1
598.15			1.0162E+2	7.4669E+1	5.9045E+1	4.8786E+1	4.1516E+1	3.6089E+1	3.1883E+1	2.8383E+1
623.15				1.5288E+2	1.0524E+2	8.0128E+1	6.4534E+1	5.3894E+1	4.6170E+1	4.022E+1
648.15				4.9104E+2	2.2435E+2	1.4538E+2	1.0690E+2	8.4095E+1	6.9022E+1	5.822E+1
673.15				1.8908E+4	7.3803E+2	3.1218E+2	1.9405E+2	1.3895E+2	1.0727E+2	8.143E+1
698.15				8.2887E+3	1.2139E+4	9.1647E+2	4.0225E+2	2.4711E+2	1.7458E+2	1.3157E+2
723.15				5.2942E+3	4.9488E+3	3.8506E+3	2.9815E+3	2.3815E+3	1.9660E+2	1.5212E+2
748.15				5.7823E+3	3.0707E+3	7.9229E+3	7.1537E+3	6.5380E+3	1.7617E+3	1.5212E+2
773.15				6.1467E+3	1.8052E+3	5.8207E+3	6.5380E+3	3.9706E+3	1.7617E+3	1.5212E+2
798.15				6.4209E+3	8.7454E+2	4.4393E+3	5.5192E+3	4.4439E+3	2.6011E+3	1.4134E+3
823.15				6.6271E+3	1.5486E+2	3.4257E+3	4.6449E+3	4.2764E+3	3.0716E+3	1.9157E+3
848.15				6.7806E+3	4.1952E+2	2.6351E+3	3.9183E+3	3.9276E+3	3.1898E+3	2.2633E+3
873.15				6.8926E+3	8.8779E+2	1.9949E+3	3.3068E+3	3.5437E+3	3.1197E+3	2.4317E+3
923.15				6.9714E+3	1.2753E+3	1.4634E+3	2.7842E+3	3.1690E+3	2.9626E+3	2.4708E+3
973.15				7.0537E+3	1.8725E+3	6.3034E+2	1.9362E+3	2.4909E+3	2.5577E+3	2.3433E+3
1023.15				7.0638E+3	2.3011E+3	1.0093E+1	1.2786E+3	1.9156E+3	2.1381E+3	2.1006E+3
1073.15				7.0249E+3	2.6129E+3	4.6427E+2	7.5677E+2	1.4314E+3	1.7466E+3	1.8256E+3
1123.15				6.9527E+3	2.8407E+3	8.3318E+2	3.3651E+2	1.0237E+3	1.3944E+3	1.5514E+3
1173.15				6.8578E+3	3.0063E+3	1.1232E+3	5.5038E+0	6.7972E+2	1.0826E+3	1.2920E+3
1223.15				6.7477E+3	3.1251E+3	1.3526E+3	2.8589E+2	3.8861E+2	8.0869E+2	1.0529E+3
1273.15				6.6277E+3	3.2080E+3	1.5347E+3	5.1697E+2	1.4167E+2	5.6898E+2	8.3584E+2
1273.15				6.5017E+3	3.2632E+3	1.6794E+3	7.0811E+2	-6.8248E+1	3.5967E+2	6.4044E+2

Table 7. (cont.) Debye Huckel limiting law slopes for apparent molar volume  $\Lambda$ , units =  $\text{cm}^3 \text{kg}^{-1/2} \text{mol}^{-3/2}$ .

T/K	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
263.15	1.3174E+0	1.2855E+0	1.2156E+0	1.1547E+0	1.0983E+0	1.0438E+0	9.9028E-1	9.3752E-1	8.8590E-1	8.3585E-1
268.15	1.3470E+0	1.3180E+0	1.2510E+0	1.1892E+0	1.1304E+0	1.0731E+0	1.0169E+0	9.6182E-1	9.0826E-1	8.5659E-1
273.15	1.3817E+0	1.3535E+0	1.2865E+0	1.2230E+0	1.1617E+0	1.1019E+0	1.0434E+0	9.8639E-1	9.3117E-1	8.7809E-1
278.15	1.4207E+0	1.3917E+0	1.3225E+0	1.2564E+0	1.1925E+0	1.1303E+0	1.0697E+0	1.0110E+0	9.5430E-1	8.9999E-1
283.15	1.4638E+0	1.4328E+0	1.3594E+0	1.2899E+0	1.2231E+0	1.1585E+0	1.0959E+0	1.0356E+0	9.7756E-1	9.2214E-1
288.15	1.5110E+0	1.4771E+0	1.3978E+0	1.3240E+0	1.2539E+0	1.1868E+0	1.1222E+0	1.0603E+0	1.0010E+0	9.4453E-1
293.15	1.5623E+0	1.5246E+0	1.4381E+0	1.3593E+0	1.2855E+0	1.2156E+0	1.1489E+0	1.0854E+0	1.0248E+0	9.6724E-1
298.15	1.6179E+0	1.5757E+0	1.4808E+0	1.3961E+0	1.3182E+0	1.2452E+0	1.1763E+0	1.1110E+0	1.0490E+0	9.9039E-1
303.15	1.6777E+0	1.6306E+0	1.5262E+0	1.4350E+0	1.3524E+0	1.2760E+0	1.2046E+0	1.1373E+0	1.0739E+0	1.0141E+0
308.15	1.7420E+0	1.6894E+0	1.5745E+0	1.4760E+0	1.3883E+0	1.3082E+0	1.2340E+0	1.1646E+0	1.0996E+0	1.0385E+0
313.15	1.8109E+0	1.7523E+0	1.6260E+0	1.5195E+0	1.4261E+0	1.3419E+0	1.2647E+0	1.1930E+0	1.1262E+0	1.0636E+0
318.15	1.8845E+0	1.8196E+0	1.6809E+0	1.5657E+0	1.4661E+0	1.3774E+0	1.2968E+0	1.2227E+0	1.1539E+0	1.0897E+0
323.15	1.9631E+0	1.8912E+0	1.7392E+0	1.6148E+0	1.5085E+0	1.4149E+0	1.3306E+0	1.2536E+0	1.1827E+0	1.1168E+0
328.15	2.0467E+0	1.9675E+0	1.8012E+0	1.6668E+0	1.5533E+0	1.4543E+0	1.3661E+0	1.2861E+0	1.2127E+0	1.1450E+0
333.15	2.1357E+0	2.0485E+0	1.8670E+0	1.7219E+0	1.6006E+0	1.4960E+0	1.4034E+0	1.3201E+0	1.2441E+0	1.1743E+0
338.15	2.2301E+0	2.1346E+0	1.9368E+0	1.7802E+0	1.6506E+0	1.5398E+0	1.4426E+0	1.3557E+0	1.2769E+0	1.2048E+0
343.15	2.3304E+0	2.2258E+0	2.0107E+0	1.8419E+0	1.7034E+0	1.5860E+0	1.4838E+0	1.3930E+0	1.3112E+0	1.2366E+0
348.15	2.4367E+0	2.3225E+0	2.0889E+0	1.9070E+0	1.7591E+0	1.6346E+0	1.5270E+0	1.4320E+0	1.3469E+0	1.2697E+0
353.15	2.5493E+0	2.4248E+0	2.1715E+0	1.9757E+0	1.8177E+0	1.6857E+0	1.5723E+0	1.4729E+0	1.3843E+0	1.3042E+0
358.15	2.6685E+0	2.5331E+0	2.2587E+0	2.0481E+0	1.8793E+0	1.7393E+0	1.6198E+0	1.5156E+0	1.4232E+0	1.3401E+0
363.15	2.7948E+0	2.6475E+0	2.3507E+0	2.1243E+0	1.9441E+0	1.7956E+0	1.6696E+0	1.5603E+0	1.4638E+0	1.3774E+0
368.15	2.9284E+0	2.7685E+0	2.4477E+0	2.2046E+0	2.0122E+0	1.8545E+0	1.7216E+0	1.6069E+0	1.5061E+0	1.4162E+0
373.15	3.0698E+0	2.8964E+0	2.5499E+0	2.2889E+0	2.0836E+0	1.9163E+0	1.7760E+0	1.6555E+0	1.5501E+0	1.4566E+0
383.15	3.3776E+0	3.1740E+0	2.7707E+0	2.4705E+0	2.2369E+0	2.0485E+0	1.8920E+0	1.7590E+0	1.6436E+0	1.5419E+0
393.15	3.7222E+0	3.4837E+0	3.0153E+0	2.6705E+0	2.4050E+0	2.1929E+0	2.0183E+0	1.8712E+0	1.7446E+0	1.6338E+0
398.15	3.9096E+0	3.6516E+0	3.1471E+0	2.7778E+0	2.4949E+0	2.2699E+0	2.0855E+0	1.9307E+0	1.7980E+0	1.6823E+0
403.15	4.1080E+0	3.8289E+0	3.2857E+0	2.8904E+0	2.5889E+0	2.3502E+0	2.1554E+0	1.9925E+0	1.8534E+0	1.7325E+0
413.15	4.5403E+0	4.2140E+0	3.5846E+0	3.1318E+0	2.7897E+0	2.5213E+0	2.3040E+0	2.1235E+0	1.9705E+0	1.8384E+0
423.15	5.0252E+0	4.6436E+0	3.9148E+0	3.3966E+0	3.0088E+0	2.7070E+0	2.4646E+0	2.2647E+0	2.0962E+0	1.9517E+0
433.15	5.5699E+0	5.1234E+0	4.2796E+0	3.6868E+0	3.2475E+0	2.9084E+0	2.6380E+0	2.4165E+0	2.2310E+0	2.0728E+0

Table 7. (cont.) Debye Huckel limiting law slopes for apparent molar volume  $A_V$ , units =  $\text{cm}^3 \text{kg}^{1/2} \text{mol}^{-3/2}$ .

T/K	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
443.15	6.1825E+0	5.6597E+0	4.6825E+0	4.0048E+0	3.5074E+0	3.1266E+0	2.8251E+0	2.5797E+0	2.3754E+0	2.2021E+0
448.15	6.5173E+0	5.9513E+0	4.8996E+0	4.1749E+0	3.6458E+0	3.2423E+0	2.9240E+0	2.6657E+0	2.4513E+0	2.2699E+0
453.15	6.8728E+0	6.2599E+0	5.1277E+0	4.3530E+0	3.7901E+0	3.3627E+0	3.0266E+0	2.7548E+0	2.5299E+0	2.3400E+0
463.15	7.6522E+0	6.9324E+0	5.6198E+0	4.7342E+0	4.0975E+0	3.6180E+0	3.2436E+0	2.9426E+0	2.6949E+0	2.4869E+0
473.15	8.5340E+0	7.6871E+0	6.1638E+0	5.1515E+0	4.4316E+0	3.8938E+0	3.4769E+0	3.1438E+0	2.8711E+0	2.6433E+0
498.15	1.1297E+1	1.0013E+1	7.7918E+0	6.3761E+0	5.3981E+0	4.6835E+0	4.1391E+0	3.7106E+0	3.3645E+0	3.0786E+0
523.15	1.5144E+1	1.3164E+1	9.8965E+0	7.9122E+0	6.5848E+0	5.6376E+0	4.9291E+0	4.3798E+0	3.9417E+0	3.5841E+0
523.15	1.5144E+1	1.3164E+1	9.8965E+0	7.9122E+0	6.5848E+0	5.6376E+0	4.9291E+0	4.3798E+0	3.9417E+0	3.5841E+0
548.15	2.0605E+1	1.7490E+1	1.2630E+1	9.8403E+0	8.0400E+0	6.7874E+0	5.8684E+0	5.1669E+0	4.6145E+0	4.1686E+0
573.15	2.8528E+1	2.3512E+1	1.6197E+1	1.2262E+1	9.8218E+0	8.1697E+0	6.9819E+0	6.0895E+0	5.3958E+0	4.8419E+0
598.15	4.0311E+1	3.2023E+1	2.0870E+1	1.5304E+1	1.1999E+1	9.8268E+0	8.2975E+0	7.1671E+0	6.2998E+0	5.6149E+0
623.15	5.8339E+1	4.4244E+1	2.7014E+1	1.9121E+1	1.4654E+1	1.1807E+1	9.8463E+0	8.4210E+0	7.3419E+0	6.4989E+0
648.15	8.6798E+1	6.2073E+1	3.5111E+1	2.3905E+1	1.7881E+1	1.4164E+1	1.1662E+1	9.8741E+0	8.5384E+0	7.5061E+0
673.15	1.3322E+2	8.8476E+1	4.5790E+1	2.9881E+1	2.1785E+1	1.6956E+1	1.3781E+1	1.1550E+1	9.9061E+0	8.6488E+0
698.15	2.1096E+2	1.2801E+2	5.9857E+1	3.7313E+1	2.6485E+1	2.0247E+1	1.6241E+1	1.3474E+1	1.1462E+1	9.9394E+0
723.15	3.4136E+2	1.8719E+2	7.8309E+1	4.6504E+1	3.2106E+1	2.4100E+1	1.9079E+1	1.5671E+1	1.3223E+1	1.1390E+1
748.15	5.4906E+2	2.7390E+2	1.0231E+2	5.7786E+1	3.8784E+1	2.8583E+1	2.2334E+1	1.8162E+1	1.5205E+1	1.3012E+1
773.15	8.4191E+2	3.9439E+2	1.3305E+2	7.1505E+1	4.6652E+1	3.3758E+1	2.6039E+1	2.0971E+1	1.7422E+1	1.4816E+1
798.15	1.1874E+3	5.4828E+2	1.7151E+2	8.7991E+1	5.5841E+1	3.9688E+1	3.0229E+1	2.4116E+1	1.9886E+1	1.6810E+1
823.15	1.5165E+3	7.2556E+2	2.1810E+2	1.0751E+2	6.6467E+1	4.6426E+1	3.4931E+1	2.7614E+1	2.2610E+1	1.9002E+1
848.15	1.7670E+3	9.0839E+2	2.7227E+2	1.3020E+2	7.8620E+1	5.4019E+1	4.0169E+1	3.1478E+1	2.5599E+1	2.1396E+1
873.15	1.9207E+3	1.0768E+3	3.3251E+2	1.5602E+2	9.2353E+1	6.2501E+1	4.5962E+1	3.5718E+1	2.8859E+1	2.3997E+1
923.15	2.0045E+3	1.3188E+3	4.6149E+2	2.1571E+2	1.2447E+2	8.2180E+1	5.9252E+1	4.5349E+1	3.6206E+1	2.9820E+1
973.15	1.9195E+3	1.4256E+3	5.8402E+2	2.8192E+2	1.6193E+2	1.0534E+2	7.4800E+1	5.6513E+1	4.4648E+1	3.6463E+1
1023.15	1.7591E+3	1.4346E+3	6.8366E+2	3.4815E+2	2.0274E+2	1.3141E+2	9.2445E+1	6.9151E+1	5.4153E+1	4.3898E+1
1073.15	1.5682E+3	1.3831E+3	7.5358E+2	4.0838E+2	2.4414E+2	1.5937E+2	1.1182E+2	8.3123E+1	6.4652E+1	5.2083E+1
1123.15	1.3692E+3	1.2962E+3	7.9475E+2	4.5859E+2	2.8336E+2	1.8785E+2	1.3233E+2	9.8180E+1	7.6032E+1	6.0955E+1
1173.15	1.1740E+3	1.1898E+3	8.1160E+2	4.9712E+2	3.1817E+2	2.1537E+2	1.5322E+2	1.1396E+2	8.8122E+1	7.0427E+1
1223.15	9.8833E+2	1.0759E+3	8.0916E+2	5.2407E+2	3.4727E+2	2.4061E+2	1.7362E+2	1.2999E+2	1.0068E+2	8.0376E+1
1273.15	8.1520E+2	9.5495E+2	7.9190E+2	5.4048E+2	3.7019E+2	2.6265E+2	1.9272E+2	1.4575E+2	1.1341E+2	9.0637E+1



Table 8. Debye Huckel limiting law slopes for apparent molar heat capacity at constant pressure  $C_{p,R}$ , units =  $(\text{kg/mol})^{-1/2}$ .

T/K	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
263.15	-1.0892E+0	-1.1273E+0	-1.2895E+0	-1.4771E+0	-1.8062E+0	-2.0805E+0	-2.3075E+0	-2.4934E+0	-2.6441E+0	-2.7646E+0
268.15	5.9263E-1	5.6628E-1	4.5353E-1	3.2226E-1	8.9505E-2	-1.0738E-1	-2.7254E-1	-4.0973E-1	-5.2239E-1	-6.1367E-1
273.15	1.6778E+0	1.6585E+0	1.5753E+0	1.4776E+0	1.3023E+0	1.1513E+0	1.0221E+0	9.1251E-1	8.2035E-1	7.4366E-1
278.15	2.4060E+0	2.3908E+0	2.3255E+0	2.2463E+0	2.1077E+0	1.9841E+0	1.8760E+0	1.7820E+0	1.7008E+0	1.6310E+0
283.15	2.9171E+0	2.9045E+0	2.8501E+0	2.7852E+0	2.6655E+0	2.5582E+0	2.4624E+0	2.3771E+0	2.3014E+0	2.2344E+0
288.15	3.2949E+0	3.2839E+0	3.2359E+0	3.1784E+0	3.0709E+0	2.9751E+0	2.8840E+0	2.8031E+0	2.7298E+0	2.6634E+0
293.15	3.5906E+0	3.5804E+0	3.5361E+0	3.4826E+0	3.3818E+0	3.2888E+0	3.2030E+0	3.1239E+0	3.0509E+0	2.9837E+0
298.15	3.8360E+0	3.8263E+0	3.7836E+0	3.7319E+0	3.6340E+0	3.5427E+0	3.4577E+0	3.3785E+0	3.3046E+0	3.2357E+0
303.15	4.0513E+0	4.0416E+0	3.9992E+0	3.9478E+0	3.8499E+0	3.7583E+0	3.6723E+0	3.5916E+0	3.5158E+0	3.4447E+0
308.15	4.2495E+0	4.2397E+0	4.1965E+0	4.1442E+0	4.0443E+0	3.9505E+0	3.8622E+0	3.7791E+0	3.7006E+0	3.6265E+0
313.15	4.4393E+0	4.4291E+0	4.3845E+0	4.3302E+0	4.2267E+0	4.1294E+0	4.0377E+0	3.9511E+0	3.8693E+0	3.7919E+0
318.15	4.6266E+0	4.6159E+0	4.5690E+0	4.5121E+0	4.4036E+0	4.3016E+0	4.2054E+0	4.1147E+0	4.0288E+0	3.9475E+0
323.15	4.8155E+0	4.8041E+0	4.7544E+0	4.6941E+0	4.5793E+0	4.4716E+0	4.3702E+0	4.2745E+0	4.1840E+0	4.0983E+0
328.15	5.0090E+0	4.9968E+0	4.9437E+0	4.8794E+0	4.7572E+0	4.6427E+0	4.5351E+0	4.4338E+0	4.3380E+0	4.2474E+0
333.15	5.2094E+0	5.1963E+0	5.1394E+0	5.0704E+0	4.9397E+0	4.8174E+0	4.7028E+0	4.5950E+0	4.4934E+0	4.3974E+0
338.15	5.4187E+0	5.4046E+0	5.3432E+0	5.2690E+0	5.1285E+0	4.9975E+0	4.8750E+0	4.7600E+0	4.6518E+0	4.5498E+0
343.15	5.6385E+0	5.6233E+0	5.5568E+0	5.4766E+0	5.3252E+0	5.1845E+0	5.0531E+0	4.9302E+0	4.8148E+0	4.7062E+0
348.15	5.8703E+0	5.8537E+0	5.7817E+0	5.6948E+0	5.5312E+0	5.3796E+0	5.2385E+0	5.1068E+0	4.9835E+0	4.8676E+0
353.15	6.1155E+0	6.0975E+0	6.0191E+0	5.9249E+0	5.7478E+0	5.5841E+0	5.4323E+0	5.2909E+0	5.1588E+0	5.0350E+0
358.15	6.3756E+0	6.3559E+0	6.2706E+0	6.1681E+0	5.9760E+0	5.7990E+0	5.6353E+0	5.4833E+0	5.3416E+0	5.2091E+0
363.15	6.6519E+0	6.6305E+0	6.5374E+0	6.4258E+0	6.2170E+0	6.0254E+0	5.8486E+0	5.6849E+0	5.5328E+0	5.3908E+0
368.15	6.9462E+0	6.9227E+0	6.8210E+0	6.6992E+0	6.4721E+0	6.2643E+0	6.0732E+0	5.8967E+0	5.7330E+0	5.5807E+0
373.15	7.2600E+0	7.2343E+0	7.1229E+0	6.9899E+0	6.7425E+0	6.5168E+0	6.3099E+0	6.1194E+0	5.9432E+0	5.7796E+0
383.15		7.9226E+0	7.7887E+0	7.6293E+0	7.3343E+0	7.0672E+0	6.8239E+0	6.6012E+0	6.3963E+0	6.2071E+0
393.15		8.7119E+0	8.5498E+0	8.3577E+0	8.0043E+0	7.6867E+0	7.3993E+0	7.1378E+0	6.8988E+0	6.6791E+0
398.15		9.1505E+0	8.9719E+0	8.7604E+0	8.3729E+0	8.0258E+0	7.7130E+0	7.4293E+0	7.1707E+0	6.9338E+0
403.15		9.6223E+0	9.4250E+0	9.1921E+0	8.7664E+0	8.3868E+0	8.0459E+0	7.7378E+0	7.4578E+0	7.2020E+0
413.15		1.0679E+1	1.0437E+1	1.0153E+1	9.6375E+0	9.1816E+0	8.7755E+0	8.4110E+0	8.0818E+0	7.7828E+0
423.15		1.1914E+1	1.1616E+1	1.1267E+1	1.0638E+1	1.0088E+1	9.6016E+0	9.1686E+0	8.7803E+0	8.4299E+0
433.15		1.3369E+1	1.2997E+1	1.2565E+1	1.1794E+1	1.1126E+1	1.0541E+1	1.0024E+1	9.5647E+0	9.1525E+0

Table 8 (cont.) Debye Huckel limiting law slopes for apparent molar heat capacity at constant pressure  $A_c/R$ , units = (kg/mol)<sup>-1/2</sup>.

T/K	p/MPa										
	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	
443.15		1.5097E+1	1.4630E+1	1.4090E+1	1.3137E+1	1.2321E+1	1.1613E+1	1.0995E+1	1.0448E+1	9.9617E+0	
448.15		1.6085E+1	1.5559E+1	1.4954E+1	1.3891E+1	1.2986E+1	1.2207E+1	1.1528E+1	1.0932E+1	1.0403E+1	
453.15			1.6576E+1	1.5896E+1	1.4707E+1	1.3703E+1	1.2843E+1	1.2098E+1	1.1446E+1	1.0870E+1	
463.15			1.8919E+1	1.8052E+1	1.6557E+1	1.5313E+1	1.4261E+1	1.3359E+1	1.2578E+1	1.1894E+1	
473.15			2.1771E+1	2.0654E+1	1.8754E+1	1.7199E+1	1.5903E+1	1.4806E+1	1.3865E+1	1.3049E+1	
498.15			3.2327E+1	3.0071E+1	2.6654E+1	2.4584E+1	2.1327E+1	1.9486E+1	1.7956E+1	1.6665E+1	
523.15			5.2391E+1	4.7192E+1	4.0719E+1	3.9377E+1	3.3798E+1	2.6388E+1	2.3809E+1	2.1706E+1	
523.15			5.2391E+1	4.7192E+1	4.0719E+1	3.9377E+1	3.3798E+1	2.6388E+1	2.3809E+1	2.1706E+1	
548.15				8.3404E+1	6.3695E+1	5.1390E+1	4.3024E+1	3.6989E+1	3.2442E+1	2.8899E+1	
573.15				1.8479E+2	1.1753E+2	8.5119E+1	6.6309E+1	5.4131E+1	4.5653E+1	3.9437E+1	
598.15					2.7995E+2	1.6176E+2	1.1124E+2	8.3815E+1	6.6828E+1	5.5370E+1	
623.15					1.3922E+3	3.9755E+2	2.1264E+2	1.4019E+2	1.0278E+2	8.0370E+1	
648.15	1.2338E+1	3.6703E+1	4.8954E+1	-8.6916E+1	-1.3317E+4	1.8211E+3	5.0346E+2	2.6066E+2	1.6800E+2	1.2115E+2	
673.15	1.1435E+1	3.3919E+1	4.5929E+1	-4.3691E+1	-1.9024E+3	2.5488E+4	1.6442E+3	5.4819E+2	2.9220E+2	1.8921E+2	
698.15	1.0629E+1	3.1488E+1	4.3536E+1	-2.0549E+1	-7.8365E+2	-5.8787E+3	4.0028E+3	1.1725E+3	5.1517E+2	2.9782E+2	
723.15	9.9063E+0	2.9342E+1	4.1514E+1	-6.5660E+0	-4.3341E+2	-1.9671E+3	-1.7680E+3	1.4448E+3	7.7418E+2	4.3497E+2	
748.15	9.2555E+0	2.7430E+1	3.9725E+1	2.5482E+0	-2.7530E+2	-1.0001E+3	-1.6924E+3	-3.8119E+1	7.0772E+2	5.1153E+2	
773.15	8.6673E+0	2.5713E+1	3.8094E+1	8.7810E+0	-1.8889E+2	-6.1544E+2	-1.0810E+3	-7.7429E+2	1.4905E+2	4.0389E+2	
798.15	8.1338E+0	2.4162E+1	3.6579E+1	1.3172E+1	-1.3573E+2	-4.2053E+2	-7.3178E+2	-7.4670E+2	-2.9874E+2	1.3060E+2	
823.15	7.6482E+0	2.2755E+1	3.5155E+1	1.6316E+1	-1.0031E+2	-3.0638E+2	-5.2855E+2	-6.0829E+2	-4.3237E+2	-1.1779E+2	
848.15	7.2051E+0	2.1473E+1	3.3807E+1	1.8582E+1	-7.5344E+1	-2.3279E+2	-4.0070E+2	-4.8825E+2	-4.2760E+2	-2.4477E+2	
873.15	6.7995E+0	2.0299E+1	3.2527E+1	2.0210E+1	-5.7005E+1	-1.8204E+2	-3.1458E+2	-3.9678E+2	-3.8558E+2	-2.8545E+2	
923.15	6.0850E+0	1.8230E+1	3.0148E+1	2.2155E+1	-3.2331E+1	-1.1756E+2	-2.0794E+2	-2.7456E+2	-2.9638E+2	-2.7026E+2	
973.15	5.4776E+0	1.6467E+1	2.7984E+1	2.2976E+1	-1.6987E+1	-7.9106E+1	-1.4569E+2	-1.9954E+2	-2.2829E+2	-2.2825E+2	
1023.15	4.9570E+0	1.4950E+1	2.6013E+1	2.3121E+1	-6.9231E+0	-5.4145E+1	-1.0556E+2	-1.4982E+2	-1.7875E+2	-1.8903E+2	
1073.15	4.5072E+0	1.3635E+1	2.4217E+1	2.2852E+1	-1.0057E-1	-3.7023E+1	-7.7969E+1	-1.1489E+2	-1.4199E+2	-1.5643E+2	
1123.15	4.1161E+0	1.2487E+1	2.2581E+1	2.230E+1	4.6162E+0	-2.4828E+1	-5.8131E+1	-8.9302E+1	-1.1401E+2	-1.2986E+2	
1173.15	3.7737E+0	1.1478E+1	2.1089E+1	2.1657E+1	7.9084E+0	-1.5913E+1	-4.3412E+1	-6.9967E+1	-9.2223E+1	-1.0818E+2	
1223.15	3.4723E+0	1.0586E+1	1.9726E+1	2.0898E+1	1.0208E+1	-9.2719E+0	-3.2239E+1	-5.5021E+1	-7.4958E+1	-9.0362E+1	
1273.15	3.2057E+0	9.7945E+0	1.8481E+1	2.0096E+1	1.1799E+1	-4.2598E+0	-2.3610E+1	-4.3267E+1	-6.1078E+1	-7.5613E+1	

Table 8. (cont.) Debye Huckel limiting law slopes for apparent molar heat capacity at constant pressure  $A_p/R$ , units =  $(\text{kg/mol})^{-1/2}$ .

T/K	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
263.15	-2.8595E+0	-2.9884E+0	-3.0937E+0	-3.0729E+0	-3.0370E+0	-3.0239E+0	-3.0417E+0	-3.0879E+0	-3.1574E+0	-3.2451E+0
268.15	-6.8646E-1	-7.8678E-1	-8.6698E-1	-8.3655E-1	-7.8357E-1	-7.4287E-1	-7.2474E-1	-7.2951E-1	-7.5415E-1	-7.9497E-1
273.15	6.8061E-1	5.8878E-1	4.9565E-1	5.0176E-1	5.3821E-1	5.7388E-1	5.9709E-1	6.0504E-1	5.9855E-1	5.7961E-1
278.15	1.5715E+0	1.4790E+0	1.3586E+0	1.3277E+0	1.3331E+0	1.3476E+0	1.3593E+0	1.3636E+0	1.3594E+0	1.3472E+0
283.15	2.1753E+0	2.0784E+0	1.9275E+0	1.8577E+0	1.8278E+0	1.8148E+0	1.8070E+0	1.7989E+0	1.7880E+0	1.7735E+0
288.15	2.6034E+0	2.5004E+0	2.3205E+0	2.2147E+0	2.1506E+0	2.1091E+0	2.0790E+0	2.0545E+0	2.0321E+0	2.0103E+0
293.15	2.9219E+0	2.8125E+0	2.6067E+0	2.4693E+0	2.3745E+0	2.3061E+0	2.2539E+0	2.2118E+0	2.1760E+0	2.1442E+0
298.15	3.1715E+0	3.0558E+0	2.8271E+0	2.6626E+0	2.5412E+0	2.4437E+0	2.3759E+0	2.3168E+0	2.2672E+0	2.2245E+0
303.15	3.3777E+0	3.2555E+0	3.0065E+0	2.8189E+0	2.6746E+0	2.5611E+0	2.4698E+0	2.3949E+0	2.3322E+0	2.2786E+0
308.15	3.5566E+0	3.4277E+0	3.1601E+0	2.9525E+0	2.7885E+0	2.6595E+0	2.5494E+0	2.4602E+0	2.3852E+0	2.3213E+0
313.15	3.7185E+0	3.5828E+0	3.2975E+0	3.0722E+0	2.8912E+0	2.7437E+0	2.6219E+0	2.5201E+0	2.4341E+0	2.3605E+0
318.15	3.8704E+0	3.7274E+0	3.4250E+0	3.1835E+0	2.9874E+0	2.8260E+0	2.6916E+0	2.5785E+0	2.4825E+0	2.4001E+0
323.15	4.0170E+0	3.8652E+0	3.5465E+0	3.2898E+0	3.0799E+0	2.9050E+0	2.7604E+0	2.6373E+0	2.5322E+0	2.4418E+0
328.15	4.1615E+0	4.0024E+0	3.6649E+0	3.3933E+0	3.1706E+0	2.9853E+0	2.8294E+0	2.6971E+0	2.5859E+0	2.4862E+0
333.15	4.3064E+0	4.1382E+0	3.7821E+0	3.4957E+0	3.2606E+0	3.0645E+0	2.8992E+0	2.7584E+0	2.6377E+0	2.5332E+0
338.15	4.4534E+0	4.2752E+0	3.8995E+0	3.5980E+0	3.3506E+0	3.1442E+0	2.9699E+0	2.8212E+0	2.6934E+0	2.5827E+0
343.15	4.6037E+0	4.4148E+0	4.0181E+0	3.7010E+0	3.4412E+0	3.2246E+0	3.0416E+0	2.8854E+0	2.7509E+0	2.6342E+0
348.15	4.7585E+0	4.5579E+0	4.1387E+0	3.8052E+0	3.5328E+0	3.3060E+0	3.1144E+0	2.9509E+0	2.8100E+0	2.6876E+0
353.15	4.9186E+0	4.7054E+0	4.2619E+0	3.9113E+0	3.6258E+0	3.3886E+0	3.1884E+0	3.0176E+0	2.8704E+0	2.7425E+0
358.15	5.0849E+0	4.8579E+0	4.3884E+0	4.0195E+0	3.7203E+0	3.4724E+0	3.2635E+0	3.0854E+0	2.9320E+0	2.7987E+0
363.15	5.2580E+0	5.0150E+0	4.5186E+0	4.1301E+0	3.8166E+0	3.5576E+0	3.3399E+0	3.1544E+0	2.9947E+0	2.8560E+0
368.15	5.4386E+0	5.1804E+0	4.6528E+0	4.2436E+0	3.9150E+0	3.6444E+0	3.4174E+0	3.2244E+0	3.0584E+0	2.9143E+0
373.15	5.6273E+0	5.3516E+0	4.7915E+0	4.3602E+0	4.0156E+0	3.7328E+0	3.4963E+0	3.2955E+0	3.1230E+0	2.9734E+0
378.15	5.8238E+0	5.5273E+0	4.9379E+0	4.4802E+0	4.1151E+0	3.8151E+0	3.582E+0	3.4410E+0	3.2551E+0	3.0941E+0
383.15	6.0318E+0	5.7164E+0	5.0837E+0	4.6035E+0	4.2240E+0	3.9151E+0	3.6582E+0	3.4912E+0	3.3908E+0	3.2178E+0
388.15	6.2476E+0	5.9099E+0	5.2399E+0	4.7320E+0	4.3322E+0	4.0151E+0	3.8261E+0	3.5912E+0	3.4601E+0	3.2808E+0
393.15	6.4765E+0	6.1146E+0	5.3979E+0	4.8620E+0	4.4432E+0	4.1053E+0	3.8261E+0	3.682E+0	3.4601E+0	3.2808E+0
398.15	6.7198E+0	6.3276E+0	5.5640E+0	4.9975E+0	4.5573E+0	4.2037E+0	3.9125E+0	3.682E+0	3.4601E+0	3.2808E+0
403.15	6.9672E+0	6.5537E+0	5.7367E+0	5.1375E+0	4.6746E+0	4.3043E+0	4.0006E+0	3.7464E+0	3.5304E+0	3.3446E+0
413.15	7.5100E+0	7.0293E+0	6.1028E+0	5.4316E+0	4.9192E+0	4.5131E+0	4.1823E+0	3.9070E+0	3.6742E+0	3.4745E+0
423.15	8.1118E+0	7.5558E+0	6.4992E+0	5.7451E+0	5.1782E+0	4.7325E+0	4.3718E+0	4.0735E+0	3.8224E+0	3.6079E+0
433.15	8.7807E+0	8.1359E+0	6.9288E+0	6.0829E+0	5.4528E+0	4.9629E+0	4.5697E+0	4.2464E+0	3.9755E+0	3.7450E+0

Table 8. (cont.) Debye Huckel limiting law slopes for apparent molar heat capacity at constant pressure  $\Lambda_c/R$ , units =  $(\text{kg/mol})^{-1/2}$ .

T/K	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
443.15	9.5258E+0	8.7764E+0	7.3949E+0	6.4438E+0	5.7443E+0	5.2057E+0	4.7766E+0	4.4260E+0	4.1337E+0	3.8860E+0
448.15	9.9303E+0	9.1215E+0	7.6428E+0	6.6339E+0	5.8967E+0	5.3318E+0	4.8836E+0	4.5185E+0	4.2148E+0	3.9580E+0
453.15	1.0358E+1	9.4846E+0	7.9012E+0	6.8307E+0	6.0538E+0	5.4613E+0	4.9931E+0	4.6128E+0	4.2973E+0	4.0311E+0
463.15	1.1289E+1	1.0269E+1	8.4516E+0	7.2459E+0	6.3825E+0	5.7308E+0	5.2197E+0	4.8072E+0	4.4668E+0	4.1808E+0
473.15	1.2334E+1	1.1140E+1	9.0502E+0	7.6914E+0	6.7317E+0	6.0148E+0	5.4570E+0	5.0097E+0	4.6424E+0	4.3351E+0
498.15	1.5560E+1	1.3768E+1	1.0789E+1	8.9531E+0	7.7031E+0	6.7938E+0	6.1005E+0	5.5534E+0	5.1100E+0	4.7429E+0
523.15	1.9959E+1	1.7226E+1	1.2942E+1	1.0458E+1	8.8314E+0	7.6809E+0	6.8220E+0	6.1552E+0	5.6217E+0	5.1848E+0
548.15	2.6064E+1	2.1819E+1	1.5609E+1	1.2246E+1	1.0136E+1	8.6872E+0	7.6282E+0	6.8194E+0	6.1807E+0	5.6633E+0
573.15	3.4698E+1	2.7973E+1	1.8904E+1	1.4360E+1	1.1636E+1	9.8213E+0	8.5238E+0	7.5489E+0	6.7891E+0	6.1798E+0
598.15	4.7170E+1	3.6289E+1	2.2959E+1	1.6837E+1	1.3344E+1	1.1088E+1	9.5105E+0	8.3445E+0	7.4470E+0	6.7346E+0
623.15	6.5617E+1	4.7617E+1	2.7912E+1	1.9708E+1	1.5264E+1	1.2486E+1	1.0586E+1	9.2037E+0	8.1527E+0	7.3263E+0
648.15	9.3535E+1	6.3134E+1	3.3902E+1	2.2988E+1	1.7392E+1	1.4007E+1	1.1742E+1	1.0120E+1	8.9014E+0	7.9515E+0
673.15	1.3620E+2	8.4334E+1	4.1053E+1	2.6674E+1	1.9708E+1	1.5633E+1	1.2966E+1	1.1084E+1	9.6855E+0	8.6045E+0
698.15	1.9912E+2	1.1257E+2	4.9429E+1	3.0737E+1	2.2180E+1	1.7339E+1	1.4237E+1	1.2081E+1	1.0494E+1	9.2770E+0
723.15	2.7896E+2	1.4736E+2	5.8944E+1	3.5114E+1	2.4761E+1	1.9090E+1	1.5531E+1	1.3091E+1	1.1313E+1	9.9584E+0
748.15	3.4568E+2	1.8310E+2	6.9203E+1	3.9894E+1	2.7392E+1	2.0846E+1	1.6817E+1	1.4093E+1	1.2125E+1	1.0636E+1
773.15	3.4651E+2	2.0710E+2	7.9302E+1	4.4301E+1	3.0001E+1	2.2562E+1	1.8066E+1	1.5063E+1	1.2913E+1	1.1296E+1
798.15	2.5262E+2	2.0553E+2	8.7732E+1	4.8671E+1	3.2502E+1	2.4196E+1	1.9246E+1	1.5978E+1	1.3659E+1	1.1923E+1
823.15	9.5968E+1	1.7321E+2	9.2633E+1	5.2444E+1	3.4796E+1	2.5702E+1	2.0330E+1	1.6818E+1	1.4344E+1	1.2503E+1
848.15	-5.0624E+1	1.1612E+2	9.2431E+1	5.5193E+1	3.6768E+1	2.7040E+1	2.1295E+1	1.7564E+1	1.4955E+1	1.3024E+1
873.15	-1.4523E+2	4.8191E+1	8.6469E+1	5.6486E+1	3.8289E+1	2.8165E+1	2.2122E+1	1.8205E+1	1.5480E+1	1.3474E+1
923.15	-2.0928E+2	-6.4477E+1	5.9711E+1	5.3482E+1	3.9442E+1	2.9605E+1	2.3299E+1	1.9139E+1	1.6251E+1	1.4141E+1
973.15	-2.0399E+2	-1.1891E+2	2.2674E+1	4.2814E+1	3.7339E+1	2.9654E+1	2.3746E+1	1.9587E+1	1.6641E+1	1.4487E+1
1023.15	-1.8213E+2	-1.3533E+2	-1.2697E+1	2.6612E+1	3.1629E+1	2.7961E+1	2.3327E+1	1.9525E+1	1.6666E+1	1.4533E+1
1073.15	-1.5836E+2	-1.3462E+2	-3.9540E+1	8.3416E+0	2.2795E+1	2.4309E+1	2.1877E+1	1.8899E+1	1.6334E+1	1.4309E+1
1123.15	-1.3644E+2	-1.2693E+2	-5.6993E+1	-8.8418E+0	1.2046E+1	1.8777E+1	1.9254E+1	1.7617E+1	1.5620E+1	1.3832E+1
1173.15	-1.1717E+2	-1.1666E+2	-6.7042E+1	-2.3089E+1	8.5782E-1	1.1808E+1	1.5431E+1	1.5580E+1	1.4465E+1	1.3087E+1
1223.15	-1.0049E+2	-1.0573E+2	-7.1981E+1	-3.3886E+1	-9.5331E+0	4.1126E+0	1.0573E+1	1.2742E+1	1.2798E+1	1.2034E+1
1273.15	-8.6130E+1	-9.5008E+1	-7.3563E+1	-4.1529E+1	-1.8402E+1	-3.5591E+0	5.0243E+0	9.1548E+0	1.0574E+1	1.0619E+1

Table 9. Debye Huckel limiting law slopes for apparent molar compressibility  $A_K$ , units =  $\text{cm}^3 \text{kg}^{-1/2} \text{mol}^{-3/2} \text{MPa}^{-1}$ .

T/K	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
263.15	-2.4666E-3	-2.4494E-3	-2.3786E-3	-2.3007E-3	-2.1708E-3	-2.0635E-3	-1.9697E-3	-1.8843E-3	-1.8047E-3	-1.7295E-3
268.15	-1.9463E-3	-1.9352E-3	-1.8897E-3	-1.8406E-3	-1.7613E-3	-1.6990E-3	-1.6470E-3	-1.6011E-3	-1.5591E-3	-1.5197E-3
273.15	-1.7897E-3	-1.7803E-3	-1.7419E-3	-1.7005E-3	-1.6344E-3	-1.5841E-3	-1.5440E-3	-1.5104E-3	-1.4810E-3	-1.4546E-3
278.15	-1.8665E-3	-1.8565E-3	-1.8150E-3	-1.7696E-3	-1.6953E-3	-1.6377E-3	-1.5918E-3	-1.5544E-3	-1.5220E-3	-1.4942E-3
283.15	-2.0997E-3	-2.0877E-3	-2.0372E-3	-1.9806E-3	-1.8853E-3	-1.8088E-3	-1.7461E-3	-1.6938E-3	-1.6495E-3	-1.6114E-3
288.15	-2.4431E-3	-2.4280E-3	-2.3646E-3	-2.2924E-3	-2.1678E-3	-2.0647E-3	-1.9782E-3	-1.9049E-3	-1.8420E-3	-1.7875E-3
293.15	-2.8683E-3	-2.8497E-3	-2.7706E-3	-2.6796E-3	-2.5199E-3	-2.3849E-3	-2.2698E-3	-2.1708E-3	-2.0849E-3	-2.0099E-3
298.15	-3.3586E-3	-3.3359E-3	-3.2391E-3	-3.1267E-3	-2.9274E-3	-2.7566E-3	-2.6091E-3	-2.4810E-3	-2.3689E-3	-2.2703E-3
303.15	-3.9045E-3	-3.8772E-3	-3.7607E-3	-3.6248E-3	-3.3819E-3	-3.1718E-3	-2.9889E-3	-2.8289E-3	-2.6880E-3	-2.5634E-3
308.15	-4.5010E-3	-4.4668E-3	-4.3308E-3	-4.1693E-3	-3.8791E-3	-3.6264E-3	-3.4052E-3	-3.2103E-3	-3.0384E-3	-2.8877E-3
313.15	-5.1468E-3	-5.1092E-3	-4.9478E-3	-4.7585E-3	-4.4170E-3	-4.1184E-3	-3.8560E-3	-3.6242E-3	-3.4186E-3	-3.2356E-3
318.15	-5.8427E-3	-5.7992E-3	-5.6122E-3	-5.3927E-3	-4.9959E-3	-4.6478E-3	-4.3409E-3	-4.0693E-3	-3.8279E-3	-3.6125E-3
323.15	-6.5912E-3	-6.5412E-3	-6.3265E-3	-6.0742E-3	-5.6172E-3	-5.2156E-3	-4.8610E-3	-4.5465E-3	-4.2667E-3	-4.0167E-3
328.15	-7.3964E-3	-7.3393E-3	-7.0942E-3	-6.8060E-3	-6.2837E-3	-5.8241E-3	-5.4180E-3	-5.0575E-3	-4.7364E-3	-4.4492E-3
333.15	-8.2634E-3	-8.1986E-3	-7.9202E-3	-7.5926E-3	-6.9989E-3	-6.4764E-3	-6.0144E-3	-5.6042E-3	-5.2386E-3	-4.9115E-3
338.15	-9.1987E-3	-9.1253E-3	-8.8101E-3	-8.4394E-3	-7.7674E-3	-7.1762E-3	-6.6535E-3	-6.1893E-3	-5.7757E-3	-5.4056E-3
343.15	-1.0210E-2	-1.0127E-2	-9.7709E-3	-9.3525E-3	-8.5945E-3	-7.9280E-3	-7.3390E-3	-6.8162E-3	-6.3505E-3	-5.9339E-3
348.15	-1.1305E-2	-1.1211E-2	-1.0810E-2	-1.0339E-2	-9.4862E-3	-8.7369E-3	-8.0753E-3	-7.4885E-3	-6.9662E-3	-6.4993E-3
353.15	-1.2494E-2	-1.2389E-2	-1.1937E-2	-1.1407E-2	-1.0449E-2	-9.6088E-3	-8.8675E-3	-8.2108E-3	-7.6266E-3	-7.1049E-3
358.15	-1.3788E-2	-1.3670E-2	-1.3162E-2	-1.2567E-2	-1.1492E-2	-1.0550E-2	-9.7211E-3	-9.0978E-3	-8.3358E-3	-7.7543E-3
363.15	-1.5199E-2	-1.5066E-2	-1.4496E-2	-1.3827E-2	-1.2622E-2	-1.1569E-2	-1.0642E-2	-9.8244E-3	-9.0984E-3	-8.4515E-3
368.15	-1.6743E-2	-1.6553E-2	-1.5952E-2	-1.5201E-2	-1.3850E-2	-1.2672E-2	-1.1638E-2	-1.0727E-2	-9.9194E-3	-9.2008E-3
373.15	-1.8434E-2	-1.8265E-2	-1.7544E-2	-1.6701E-2	-1.5187E-2	-1.3870E-2	-1.2717E-2	-1.1702E-2	-1.0805E-2	-1.0007E-2
383.15	-2.2122E-2	-2.1911E-2	-2.1208E-2	-2.0142E-2	-1.8238E-2	-1.6591E-2	-1.5156E-2	-1.3900E-2	-1.2793E-2	-1.1813E-2
393.15	-2.6811E-2	-2.6538E-2	-2.5647E-2	-2.4296E-2	-2.1894E-2	-1.9830E-2	-1.8043E-2	-1.6486E-2	-1.5122E-2	-1.3919E-2
398.15	-2.9538E-2	-2.9266E-2	-2.8222E-2	-2.6697E-2	-2.3994E-2	-2.1681E-2	-1.9685E-2	-1.7951E-2	-1.6435E-2	-1.5103E-2
403.15	-3.2566E-2	-3.1074E-2	-2.9350E-2	-2.7306E-2	-2.4371E-2	-2.1710E-2	-1.9479E-2	-1.7546E-2	-1.5862E-2	-1.4385E-2
413.15	-3.9690E-2	-3.7766E-2	-3.5551E-2	-3.2969E-2	-2.9699E-2	-2.6389E-2	-2.3592E-2	-2.1186E-2	-1.9103E-2	-1.7286E-2
423.15	-4.8596E-2	-4.6090E-2	-4.3223E-2	-3.9838E-2	-3.5551E-2	-3.1406E-2	-2.7644E-2	-2.4338E-2	-2.1495E-2	-1.9286E-2
433.15	-5.9844E-2	-5.6547E-2	-5.2799E-2	-4.8545E-2	-4.3455E-2	-3.8688E-2	-3.4243E-2	-3.0268E-2	-2.6768E-2	-2.3775E-2

Table 9 (cont.) Debye Huckel limiting law slopes for apparent molar compressibility  $A_{\kappa}$ , units =  $\text{cm}^3 \text{kg}^{-1/2} \text{mol}^{-3/2} \text{MPa}^{-1}$ .

T/K	p/MPa									
	0.1	1.0	5.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
443.15		-7.4207E-2	-6.9819E-2	-6.4867E-2	-5.6432E-2	-4.9549E-2	-4.3855E-2	-3.9088E-2	-3.5055E-2	-3.1614E-2
448.15		-8.2880E-2	-7.7794E-2	-7.2077E-2	-6.2397E-2	-5.4555E-2	-4.8106E-2	-4.2737E-2	-3.8218E-2	-3.4376E-2
453.15			-8.6857E-2	-8.0234E-2	-6.9095E-2	-6.0139E-2	-5.2823E-2	-4.6766E-2	-4.1693E-2	-3.7400E-2
463.15			-1.0900E-1	-1.0003E-1	-8.5141E-2	-7.3573E-2	-6.3898E-2	-5.6150E-2	-4.9731E-2	-4.4350E-2
473.15			-1.3820E-1	-1.2584E-1	-1.0569E-1	-9.0055E-2	-7.7673E-2	-6.7689E-2	-5.9515E-2	-5.2735E-2
498.15			-2.6464E-1	-2.3481E-1	-1.8871E-1	-1.5511E-1	-1.2982E-1	-1.1029E-1	-9.4863E-2	-8.2466E-2
523.15			-5.6736E-1	-4.8290E-1	-3.6281E-1	-2.8301E-1	-2.2714E-1	-1.8642E-1	-1.5580E-1	-1.3215E-1
523.15			-5.6736E-1	-4.8290E-1	-3.6281E-1	-2.8301E-1	-2.2714E-1	-1.8642E-1	-1.5580E-1	-1.3215E-1
548.15				-1.1576E+0	-7.7682E-1	-5.5894E-1	-4.2209E-1	-3.3027E-1	-2.6556E-1	-2.1819E-1
573.15				-3.6902E+0	-1.9746E+0	-1.2377E+0	-8.5072E-1	-6.2137E-1	-4.7390E-1	-3.7332E-1
598.15					-6.9436E+0	-3.2817E+0	-1.9229E+0	-1.2649E+0	-8.9512E-1	-6.6640E-1
623.15					-6.0016E+1	-1.2093E+1	-5.1699E+0	-2.8645E+0	-1.8157E+0	-1.2508E+0
648.15	8.4189E+5	2.8267E+4	3.3393E+3	1.7807E+3	5.7513E+3	-9.7996E+1	-1.8515E+1	-7.5258E+0	-4.0279E+0	-2.4896E+0
673.15	8.1037E+5	2.7124E+4	3.1294E+3	1.5431E+3	1.3311E+3	-6.3680E+3	-1.0754E+2	-2.4093E+1	-9.9277E+0	-5.2814E+0
698.15	7.8112E+5	2.6070E+4	2.9501E+3	1.3833E+3	8.2815E+2	3.8494E+2	-7.5357E+2	-9.093E+1	-2.6705E+1	-1.1795E+1
723.15	7.5390E+5	2.5093E+4	2.7939E+3	1.2671E+3	6.4813E+2	2.9502E+2	-5.1211E+2	-2.6774E+2	-6.9309E+1	-2.6194E+1
748.15	7.2852E+5	2.4188E+4	2.6559E+3	1.1750E+3	5.5481E+2	2.5051E+2	-1.2122E+2	-3.0475E+2	-1.3522E+2	-5.1757E+1
773.15	7.0478E+5	2.3345E+4	2.5326E+3	1.0993E+3	4.9603E+2	2.2922E+2	-1.1279E+1	-1.7891E+2	-1.6116E+2	-8.1006E+1
798.15	6.8255E+5	2.2559E+4	2.4214E+3	1.0354E+3	4.5429E+2	2.1624E+2	3.3637E+1	-9.4353E+1	-1.3042E+2	-9.4661E+1
823.15	6.6167E+5	2.1825E+4	2.3204E+3	9.8006E+2	4.2224E+2	2.0676E+2	5.6996E+1	-4.6208E+1	-9.1623E+1	-8.7288E+1
848.15	6.4203E+5	2.1138E+4	2.2282E+3	9.3146E+2	3.9628E+2	1.9895E+2	7.0705E+1	-1.6420E+1	-6.1561E+1	-7.1180E+1
873.15	6.2353E+5	2.0492E+4	2.1436E+3	8.8821E+2	3.7445E+2	1.9207E+2	7.9218E+1	3.4102E+0	-3.9487E+1	-5.5059E+1
923.15	5.8955E+5	1.9314E+4	1.9932E+3	8.1408E+2	3.3900E+2	1.7986E+2	8.7924E+1	2.7260E+1	-1.0434E+1	-2.9818E+1
973.15	5.5908E+5	1.8265E+4	1.8634E+3	7.5240E+2	3.1074E+2	1.6897E+2	9.0820E+1	4.0040E+1	7.0133E+0	-1.2576E+1
1023.15	5.3161E+5	1.7325E+4	1.7501E+3	6.9996E+2	2.8727E+2	1.5904E+2	9.0799E+1	4.7083E+1	1.7969E+1	-6.7191E-1
1073.15	5.0672E+5	1.6478E+4	1.6502E+3	6.5469E+2	2.6727E+2	1.4995E+2	8.9221E+1	5.0836E+1	2.4967E+1	7.6403E+0
1123.15	4.8405E+5	1.5710E+4	1.5614E+3	6.1511E+2	2.4993E+2	1.4163E+2	8.6804E+1	5.2595E+1	2.9421E+1	1.3465E+1
1173.15	4.6333E+5	1.5012E+4	1.4819E+3	5.8017E+2	2.3469E+2	1.3399E+2	8.3954E+1	5.3098E+1	3.2182E+1	1.7530E+1
1223.15	4.4431E+5	1.4373E+4	1.4103E+3	5.4906E+2	2.2119E+2	1.2698E+2	8.0911E+1	5.2808E+1	3.3791E+1	2.0331E+1
1273.15	4.2680E+5	1.3787E+4	1.3454E+3	5.2119E+2	2.0911E+2	1.2055E+2	7.7817E+1	5.2013E+1	3.4607E+1	2.2216E+1

Table 9. (cont.) Debye Huckel limiting law slopes for apparent molar compressibility  $A_{\kappa}$ , units =  $\text{cm}^3 \text{kg}^{1/2} \text{mol}^{-3/2} \text{NPa}^{-1}$ .

T/K	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
263.15	-1.6585E-3	-1.5295E-3	-1.2900E-3	-1.1605E-3	-1.1028E-3	-1.0789E-3	-1.0639E-3	-1.0451E-3	-1.0182E-3	-9.8264E-4
268.15	-1.4823E-3	-1.4134E-3	-1.2789E-3	-1.1995E-3	-1.1584E-3	-1.1347E-3	-1.1136E-3	-1.0874E-3	-1.0536E-3	-1.0123E-3
273.15	-1.4302E-3	-1.3861E-3	-1.2997E-3	-1.2442E-3	-1.2096E-3	-1.1834E-3	-1.1563E-3	-1.1235E-3	-1.0840E-3	-1.0381E-3
278.15	-1.4696E-3	-1.4274E-3	-1.3491E-3	-1.2971E-3	-1.2600E-3	-1.2280E-3	-1.1942E-3	-1.1535E-3	-1.1106E-3	-1.0608E-3
283.15	-1.5781E-3	-1.5224E-3	-1.4243E-3	-1.3602E-3	-1.3128E-3	-1.2715E-3	-1.2297E-3	-1.1843E-3	-1.1348E-3	-1.0814E-3
288.15	-1.7398E-3	-1.6604E-3	-1.5228E-3	-1.4344E-3	-1.3702E-3	-1.3163E-3	-1.2651E-3	-1.2128E-3	-1.1580E-3	-1.1009E-3
293.15	-1.9439E-3	-1.8335E-3	-1.6421E-3	-1.5204E-3	-1.4339E-3	-1.3644E-3	-1.3020E-3	-1.2417E-3	-1.1813E-3	-1.1203E-3
298.15	-2.1832E-3	-2.0365E-3	-1.7806E-3	-1.6183E-3	-1.5048E-3	-1.4168E-3	-1.3416E-3	-1.2723E-3	-1.2057E-3	-1.1404E-3
303.15	-2.4527E-3	-2.2655E-3	-1.9368E-3	-1.7280E-3	-1.5837E-3	-1.4474E-3	-1.3849E-3	-1.3053E-3	-1.2319E-3	-1.1618E-3
308.15	-2.7495E-3	-2.5182E-3	-2.1097E-3	-1.8495E-3	-1.6709E-3	-1.5386E-3	-1.4327E-3	-1.3421E-3	-1.2607E-3	-1.1851E-3
313.15	-3.0720E-3	-2.7934E-3	-2.2987E-3	-1.9826E-3	-1.7668E-3	-1.6090E-3	-1.4854E-3	-1.3824E-3	-1.2924E-3	-1.2108E-3
318.15	-3.4196E-3	-3.0904E-3	-2.5034E-3	-2.1275E-3	-1.8715E-3	-1.6861E-3	-1.5434E-3	-1.4269E-3	-1.3274E-3	-1.2390E-3
323.15	-3.7926E-3	-3.4092E-3	-2.7240E-3	-2.2841E-3	-1.9852E-3	-1.7703E-3	-1.6088E-3	-1.4758E-3	-1.3659E-3	-1.2702E-3
328.15	-4.1916E-3	-3.7505E-3	-2.9605E-3	-2.4527E-3	-2.1081E-3	-1.8616E-3	-1.6761E-3	-1.5294E-3	-1.4082E-3	-1.3044E-3
333.15	-4.6180E-3	-4.1152E-3	-3.2136E-3	-2.6336E-3	-2.2404E-3	-1.9604E-3	-1.7513E-3	-1.5877E-3	-1.4544E-3	-1.3418E-3
338.15	-5.0735E-3	-4.5045E-3	-3.4838E-3	-2.8271E-3	-2.3824E-3	-2.0668E-3	-1.8326E-3	-1.6510E-3	-1.5047E-3	-1.3825E-3
343.15	-5.5602E-3	-4.9200E-3	-3.7721E-3	-3.0337E-3	-2.5344E-3	-2.1811E-3	-1.9202E-3	-1.7195E-3	-1.5591E-3	-1.4267E-3
348.15	-6.0805E-3	-5.3637E-3	-4.0794E-3	-3.2541E-3	-2.6968E-3	-2.3034E-3	-2.0142E-3	-1.7931E-3	-1.6179E-3	-1.4745E-3
353.15	-6.6373E-3	-5.8375E-3	-4.4068E-3	-3.4889E-3	-2.8700E-3	-2.4342E-3	-2.1149E-3	-1.8721E-3	-1.6811E-3	-1.5259E-3
358.15	-7.2336E-3	-6.3440E-3	-4.7558E-3	-3.7389E-3	-3.0544E-3	-2.5736E-3	-2.2224E-3	-1.9567E-3	-1.7488E-3	-1.5810E-3
363.15	-7.8729E-3	-6.8857E-3	-5.1276E-3	-4.0048E-3	-3.2506E-3	-2.7220E-3	-2.3371E-3	-2.0470E-3	-1.8211E-3	-1.6400E-3
368.15	-8.5589E-3	-7.4656E-3	-5.5239E-3	-4.2877E-3	-3.4592E-3	-2.8797E-3	-2.4591E-3	-2.1431E-3	-1.8982E-3	-1.7029E-3
373.15	-9.2960E-3	-8.0869E-3	-5.9464E-3	-4.5885E-3	-3.6807E-3	-3.0473E-3	-2.5887E-3	-2.2453E-3	-1.9803E-3	-1.7699E-3
383.15	-1.0942E-2	-9.4678E-3	-6.8778E-3	-5.2483E-3	-4.1654E-3	-3.4136E-3	-2.8719E-3	-2.4687E-3	-2.1597E-3	-1.9164E-3
393.15	-1.2854E-2	-1.1061E-2	-7.9387E-3	-5.9941E-3	-4.7107E-3	-3.8246E-3	-3.1894E-3	-2.7191E-3	-2.3607E-3	-2.0805E-3
398.15	-1.3925E-2	-1.1948E-2	-8.5239E-3	-6.4027E-3	-5.0082E-3	-4.0482E-3	-3.3619E-3	-2.8550E-3	-2.4698E-3	-2.1695E-3
403.15	-1.5083E-2	-1.2904E-2	-9.1491E-3	-6.8372E-3	-5.3236E-3	-4.2848E-3	-3.5441E-3	-2.9984E-3	-2.5848E-3	-2.2633E-3
413.15	-1.7693E-2	-1.5043E-2	-1.0532E-2	-7.7907E-3	-6.0119E-3	-4.7993E-3	-3.9394E-3	-3.3091E-3	-2.8337E-3	-2.4660E-3
423.15	-2.0759E-2	-1.7533E-2	-1.2115E-2	-8.8695E-3	-6.7846E-3	-5.3737E-3	-4.3790E-3	-3.6536E-3	-3.1091E-3	-2.6900E-3
433.15	-2.4374E-2	-2.0441E-2	-1.3929E-2	-1.0091E-2	-7.6517E-3	-6.0144E-3	-4.8672E-3	-4.0349E-3	-3.4131E-3	-2.9367E-3

Table 9. (cont.) Debye Huckel limiting law slopes for apparent molar compressibility  $A_K$ , units =  $\text{cm}^3 \text{kg}^{1/2} \text{mol}^{-3/2} \text{MPa}^{-1}$ .

T/K	p/MPa									
	80.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
443.15	-2.8652E-2	-2.3845E-2	-1.6012E-2	-1.1674E-2	-8.6247E-3	-6.7284E-3	-5.4085E-3	-4.4561E-3	-3.7490E-3	-3.2079E-3
448.15	-3.1083E-2	-2.5763E-2	-1.7167E-2	-1.2233E-2	-9.1547E-3	-7.1153E-3	-5.7006E-3	-4.6828E-3	-3.9278E-3	-3.3531E-3
453.15	-3.3734E-2	-2.7842E-2	-1.8406E-2	-1.3041E-2	-9.7161E-3	-7.5235E-3	-6.0080E-3	-4.9207E-3	-4.1162E-3	-3.5052E-3
463.15	-3.9794E-2	-3.2550E-2	-2.1162E-2	-1.4819E-2	-1.0940E-2	-8.4084E-3	-6.6714E-3	-5.4325E-3	-4.5203E-3	-3.8305E-3
473.15	-4.7048E-2	-3.8109E-2	-2.4339E-2	-1.6835E-2	-1.2314E-2	-9.3928E-3	-7.4047E-3	-5.9955E-3	-4.9632E-3	-4.1860E-3
498.15	-7.2347E-2	-5.6971E-2	-3.4607E-2	-2.3149E-2	-1.6522E-2	-1.2361E-2	-9.5896E-3	-7.6574E-3	-6.2609E-3	-5.2213E-3
523.15	-1.1351E-1	-8.6334E-2	-4.9429E-2	-3.1836E-2	-2.2122E-2	-1.6218E-2	-1.2377E-2	-9.7481E-3	-7.8752E-3	-6.4976E-3
523.15	-1.1351E-1	-8.6334E-2	-4.9429E-2	-3.1836E-2	-2.2122E-2	-1.6218E-2	-1.2377E-2	-9.7481E-3	-7.8752E-3	-6.4976E-3
548.15	-1.8244E-1	-1.3294E-1	-7.0980E-2	-4.3809E-2	-2.9567E-2	-2.1214E-2	-1.5918E-2	-1.2364E-2	-9.8706E-3	-8.0598E-3
573.15	-3.0161E-1	-2.0844E-1	-1.0251E-1	-6.0321E-2	-3.9441E-2	-2.7658E-2	-2.0392E-2	-1.5617E-2	-1.2321E-2	-9.9590E-3
598.15	-5.1500E-1	-3.3326E-1	-1.4888E-1	-8.3075E-2	-5.2493E-2	-3.5932E-2	-2.6016E-2	-1.9639E-2	-1.5312E-2	-1.2253E-2
623.15	-9.1212E-1	-5.4393E-1	-2.1729E-1	-1.1436E-1	-6.9666E-2	-4.6497E-2	-3.3040E-2	-2.4579E-2	-1.8938E-2	-1.5004E-2
648.15	-1.6822E+0	-9.0652E-1	-3.1833E-1	-1.5719E-1	-9.2126E-2	-5.9894E-2	-4.1751E-2	-3.0604E-2	-2.3304E-2	-1.8282E-2
673.15	-3.2336E+0	-1.5404E+0	-4.6732E-1	-2.1548E-1	-1.2128E-1	-7.6749E-2	-5.2470E-2	-3.7896E-2	-2.8519E-2	-2.2158E-2
698.15	-6.4202E+0	-2.6542E+0	-6.8581E-1	-2.9418E-1	-1.5880E-1	-9.7770E-2	-6.5546E-2	-4.6647E-2	-3.4699E-2	-2.6706E-2
723.15	-1.2751E+1	-4.5749E+0	-1.0026E+0	-3.9932E-1	-2.0660E-1	-1.2373E-1	-8.1348E-2	-5.7055E-2	-4.1960E-2	-3.1999E-2
748.15	-2.3820E+1	-7.6949E+0	-1.4523E+0	-5.3787E-1	-2.6679E-1	-1.5545E-1	-1.0026E-1	-6.9318E-2	-5.0416E-2	-3.8106E-2
773.15	-3.9064E+1	-1.2226E+1	-2.0696E+0	-7.1726E-1	-3.4161E-1	-1.9380E-1	-1.2265E-1	-8.3628E-2	-6.0173E-2	-4.5093E-2
798.15	-5.3700E+1	-1.7852E+1	-2.8760E+0	-9.4421E-1	-4.3326E-1	-2.3960E-1	-1.4891E-1	-1.0017E-1	-7.1330E-2	-5.3015E-2
823.15	-6.1121E+1	-2.3639E+1	-3.8635E+0	-1.2230E+0	-5.4360E-1	-2.9362E-1	-1.7936E-1	-1.1911E-1	-8.3975E-2	-6.1923E-2
848.15	-5.9605E+1	-2.8322E+1	-4.9851E+0	-1.5534E+0	-6.7380E-1	-3.5650E-1	-2.1432E-1	-1.4058E-1	-9.8180E-2	-7.1855E-2
873.15	-5.2812E+1	-3.0909E+1	-6.1618E+0	-1.9290E+0	-8.2394E-1	-4.2861E-1	-2.5400E-1	-1.6473E-1	-1.1401E-1	-8.2842E-2
923.15	-3.6251E+1	-2.9822E+1	-8.3141E+0	-2.7587E+0	-1.1767E+0	-6.0021E-1	-3.4798E-1	-2.2131E-1	-1.5071E-1	-1.0807E-1
973.15	-2.2266E+1	-2.4506E+1	-9.7153E+0	-3.5644E+0	-1.5710E+0	-8.0276E-1	-4.6057E-1	-2.8899E-1	-1.9424E-1	-1.3770E-1
1023.15	-1.1522E+1	-1.8488E+1	-1.0156E+1	-4.2053E+0	-1.9567E+0	-1.0219E+0	-5.8795E-1	-3.6678E-1	-2.4438E-1	-1.7168E-1
1073.15	-3.3916E+0	-1.2936E+1	-9.8141E+0	-4.6062E+0	-2.2836E+0	-1.2366E+0	-7.2275E-1	-4.5224E-1	-3.0033E-1	-2.0974E-1
1123.15	2.7263E+0	-8.1232E+0	-8.9834E+0	-4.7640E+0	-2.5193E+0	-1.4246E+0	-8.5468E-1	-5.4122E-1	-3.6048E-1	-2.5128E-1
1173.15	7.3054E+0	-4.0703E+0	-7.8964E+0	-4.7206E+0	-2.6554E+0	-1.5695E+0	-9.7261E-1	-6.2817E-1	-4.2236E-1	-2.9522E-1
1223.15	1.0708E+1	-7.1737E-1	-6.6989E+0	-4.5292E+0	-2.7016E+0	-1.6641E+0	-1.0673E+0	-7.0693E-1	-4.8271E-1	-3.4000E-1
1273.15	1.3210E+1	2.0194E+0	-5.4780E+0	-4.2366E+0	-2.6756E+0	-1.7107E+0	-1.1337E+0	-7.7204E-1	-5.3787E-1	-3.8359E-1



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## 7. References

- <sup>1</sup>H. L. Friedman, *J. Chem. Phys.* **32**, 1351 (1960).
- <sup>2</sup>D. J. Bradley, K. S. Pitzer, *J. Phys. Chem.* **83**, 1599 (1979).
- <sup>3</sup>M. Uematsu, E. U. Franck, *J. Phys. Chem. Ref. Data* **9**, 1291 (1980).
- <sup>4</sup>J. A. Gates, Ph.D. Dissertation, Univ. of Delaware (1985).
- <sup>5</sup>D. G. Archer, *J. Solution Chem.* **15**, 727 (1986).
- <sup>6</sup>P. R. Tremaine, K. Sway, J. A. Barbero, *J. Solution Chem.* **15**, 1 (1986).
- <sup>7</sup>J. A. Gates, D. M. Tillett, D. E. White, R. H. Wood, *J. Chem. Thermodyn.* **19**, 131 (1987).
- <sup>8</sup>H. F. Holmes, R. H. Busey, J. M. Simonson, R. E. Mesmer, D. G. Archer, R. H. Wood, *J. Chem. Thermodyn.* **19**, 863 (1987).
- <sup>9</sup>J. Ananthaswamy, G. Atkinson, *J. Chem. Eng. Data* **29**, 81 (1984).
- <sup>10</sup>R. P. Beyer, B. R. Staples, *J. Solution Chem.* **15**, 749 (1986). The results shown in this reference as being from I. L. Khodakovskiy and V. A. Dorofeeva, *Geokhimiya* **8**, 1174 (1981) appear to be in error. For example, values of  $(\partial\epsilon/\partial p)_T$  for 298.15 K calculated from Khodakovskiy's equation are only 0.5% different from those calculated from the Pitzer and Bradley equation, whereas Fig. 3 of Ref. 10 shows differences of 5 to 10%. J. G. Kirkwood, *J. Chem. Phys.* **7**, 911 (1939).
- K. Heger, M. Uematsu, E. U. Franck, *Ber. Bunsenges. Phys. Chem.* **84**, 758 (1980).
- R. Deul, Ph.D. Dissertation, University of Karlsruhe (1984).
- <sup>14</sup>L. Haar, J. S. Gallagher, G. S. Kell, NBS/NRC Steam Tables (Hemisphere, Washington) (1984).
- <sup>15</sup>A. Saul, W. Wagner, *J. Phys. Chem. Ref. Data* (accepted).
- <sup>16</sup>P. G. Hill, *J. Phys. Chem. Ref. Data* (submitted).
- <sup>17</sup>G. S. Kell, E. Whalley, *J. Chem. Phys.* **62**, 3496 (1975).
- <sup>18</sup>L. Ter Minassian, P. Pruzan, A. Souldard, *J. Chem. Phys.* **75**, 3064 (1981).
- <sup>19</sup>R. J. Speedy, C. A. Angell, *J. Chem. Phys.* **65**, 851 (1976).
- <sup>20</sup>J. B. Hasted, M. Shahidi, *Nature* **262**, 777 (1976).
- <sup>21</sup>I. M. Hodge, C. A. Angell, *J. Chem. Phys.* **68**, 1363 (1978).
- <sup>22</sup>G. C. Akerlof, H. I. Oshry, *Trans. Faraday Soc.* **72**, 2844 (1950).
- <sup>23</sup>H. I. Oshry, Ph.D. Dissertation, University of Pittsburgh (1949).
- <sup>24</sup>D. Bertolini, M. Cassettari, G. Salvetti, *J. Chem. Phys.* **76**, 3285 (1982).
- <sup>25</sup>C. G. Malmberg, A. A. Maryott, *J. Res. Nat. Bur. Std.* **56**, 1 (1956).
- <sup>26</sup>C. E. Milner, Ph.D. Dissertation, Yale University (1955).
- <sup>27</sup>H. L. Cogan, Ph.D. Dissertation, Yale University (1958).
- <sup>28</sup>W. L. Lees, Ph.D. Dissertation, Harvard University (1949).
- <sup>29</sup>L. A. Dunn, R. H. Stokes, *Trans. Faraday Soc.* **65**, 2906 (1969).
- <sup>30a</sup>E. W. Rusche, Ph.D. Dissertation, New Mexico State University (1966) by E. W. Rusche, W. B. Good, *J. Chem. Phys.* **45**, 4667 (1966).
- <sup>31a</sup>K. R. Srinivasan, Ph.D. Dissertation, Carnegie-Mellon University (1973) by K. R. Srinivasan, R. L. Kay, *J. Chem. Phys.* **60**, 3645 (1974).
- <sup>32</sup>G. A. Vidulich, D. F. Evans, R. L. Kay, *J. Phys. Chem.* **71**, 656 (1967).
- <sup>33</sup>R. L. Kay, G. A. Vidulich, K. S. Pribadi, *J. Phys. Chem.* **73**, 445 (1969).
- <sup>34</sup>B. B. Owen, R. C. Miller, C. E. Milner, H. L. Cogan, *J. Phys. Chem.* **65**, 2065 (1961).
- <sup>35</sup>U. Kaatz, V. Uhlendorf, *Z. Phys. Chem. (Neue Folge)* **126**, 151 (1981).
- <sup>36</sup>J. K. Fogo, S. W. Benson, C. S. Copeland, *J. Chem. Phys.* **22**, 209 (1959).
- <sup>37</sup>Lukashov, Y. M., Goluhev, B. P., Ripol-Saragosy, F. B., *Teplotnergetika (Moscow)* **22**, 79 (1975).
- <sup>38</sup>T. E. Gier, H. S. Young, as reported by A. W. Lawson, A. J. Hughes, in *High Pressure Physics and Chemistry Vol. I*, R. S. Bradley, Ed. (Academic Press, New York) (1963).
- <sup>39</sup>H. C. Helgeson, D. H. Kirkham, *Am. J. Sci.* **274**, 1089 (1974).
- <sup>40</sup>R. J. Speedy, *J. Phys. Chem.* **86**, 982 (1982).
- <sup>41</sup>A. S. Quist, W. L. Marshall, *J. Phys. Chem.* **9**, 3165 (1965).
- <sup>42</sup>K. S. Pitzer, *Proc. Natl. Acad. Sci. USA* **80**, 4575 (1983).
- <sup>43</sup>H. Kanno, C. A. Angell, *J. Chem. Phys.* **73**, 1940 (1980).