# REPORT 1037

## GENERAL METHOD AND THERMODYNAMIC TABLES FOR COMPUTATION OF EQUILIBRIUM COMPOSITION AND TEMPERATURE OF CHEMICAL REACTIONS [1]

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### SUMMARY

*A rapidly convergent successive approximation process is described that simultaneously determines both composition and temperature resulting from a chemical reaction. This method is suitable for use with any set of reactants over the complete range of mixture ratios as long as the products of reaction are ideal gases. An approximate treatment of limited amounts of liquids and solids is also included. This method is particularly suited to problems having a large number of products of reaction and to problems that require determination of such properties as specific heat or velocity of sound of a dissociating mixture.*

*The method presented is applicable to a wide variety of problems that include (1) combustion at constant pressure or volume; and (2) isentropic expansion to an assigned pressure, temperature, or Mach number. Tables of thermodynamic functions needed with this method are included for 42 substances for convenience in numerical computations.*


### INTRODUCTION

The theoretical performance of propulsion systems having high combustion temperatures can be calculated on the assumption that chemical equilibrium exists among the products of reaction. The equilibrium composition and the temperature for a system of $N$ products of reaction are determined by the simultaneous solution of at least $N+1$ equations involving dissociation, mass balance, and energy or entropy balance. This calculation becomes increasingly difficult as $N$ increases.

Numerous methods for solving these equations may be found in the literature that provide a successive approximation or trial-and-error process for determining the composition at an assumed temperature and pressure. Examples of these methods are found in references 1 to 4. When it is desired to find the temperature of a system in equilibrium, with a parameter such as entropy or enthalpy assigned, the composition is usually computed at a sequence of temperatures that either converge to the correct temperature or are spaced to permit interpolation to obtain the correct temperature.

A rapidly convergent successive approximation process that determines composition at an assigned temperature or that simultaneously determines both composition and temperature for assigned values of another parameter, such as enthalpy or entropy, was developed at the NACA Lewis laboratory during 1948 and is presented herein. This process also permits computation of the partial derivatives required to compute such thermodynamic properties as specific heat and velocity of sound corresponding to chemical equilibrium. The equations are derived that are required for solution of the following cases: (1) combustion at constant pressure or volume; and (2) isentropic expansion to an assigned pressure, temperature, or Mach number. Examples are given for (1) constant-pressure adiabatic combustion; (2) isentropic expansion to an assigned pressure; and (3) isentropic expansion to an assigned Mach number.

This method is particularly suitable for problems having a large number of products of reaction and for problems that require determination of partial derivatives. Although it is possible, at least in special cases, to devise a procedure that involves less numerical computation, the method presented is applicable in a wide variety of cases and its numerical application to a given process is always simple and essentially the same for all reactions.

Tables of thermodynamic functions are needed for computing equilibrium compositions and temperature of chemical reactions. Tables containing the functions specific heat at constant pressure $C_p^\circ$, sensible enthalpy $H_T^\circ - H_0^\circ$, and molar entropy $S_T^\circ$ exist for at least part of the desired temperature range for most of the substances of interest in the analysis of aircraft-propulsion systems. Several special functions are required for convenient use with the method described herein; tables were therefore prepared, from January to June 1949, that contain, in addition to $C_p^\circ$, $H_T^\circ - H_0^\circ$, and $S_T^\circ$, assigned values of enthalpy $H_T^\circ$ and values of log $K$ and $\frac{-\Delta H^\circ}{RT}$ (logarithm of equilibrium constant and enthalpy change divided by gas constant times temperature, respectively, for reaction of formation of a substance from its elements in atomic gas state).

The data selected from various sources or computed by the NACA have been smoothed, interpolated to every 100°, and extended to 6000° K. A high degree of self-consistency has been maintained in the temperature range from 1000° to 6000° K by computing from specific-heat data the values of the other functions and retaining, in general, more decimal places than are significant. Interpolation formulas are given that permit computation of self-consistent values for all the functions at any temperature between 1000° and 6000° K.

[1] Supersedes NACA TN 2113, "General Method for Computation of Equilibrium Composition and Temperature of Chemical Reactions" by Vearl N. Huff and Virginia E. Morrell, 1950, and NACA TN 2161, "Tables of Thermodynamic Functions for Analysis of Aircraft-Propulsion Systems" by Vearl N. Huff and Sanford Gordon, 1950.

## GENERAL METHOD

The thermodynamic state following a specific process, such as combustion at constant pressure, can be determined from an appropriate combination of the following equations: (a) dissociative equilibrium; (b) conservation of mass; (c) conservation of energy; (d) pressure; and (e) entropy. Equations (a) and (b) are used to specify chemical equilibrium and, when used with any two of the remaining equations, define a process.

The successive approximation procedure presented herein for finding the simultaneous solution of a specific combination of equations (a) to (e) consists of the following steps:

(1) Estimates of composition and temperature are made and used in simple equations to compute the values of error parameters, which indicate inconsistency among the estimates of composition and temperature. (These estimates need not be based on previous experience, but for rapid convergence it is desirable that they be close to the final values.)

(2) A set of linear simultaneous correction equations is given that determine a new composition and a new temperature.

(3) The new composition is used to compute new values of the error parameters and step (2) is repeated until the desired accuracy is obtained.

### EQUATIONS FOR DISSOCIATION, MASS, PRESSURE, AND VOLUME

The substances entering a reaction process will be designated the reactants and can be represented by the equivalent formula

$$Z_{a_o}Y_{b_o}\ldots$$

where the subscripts $a_o$, $b_o$, . . . , are proportional to the total number of atoms of the elements $Z$, $Y$, . . . , respectively, contained in a quantity of the entering substance at the initial conditions. (A complete list of symbols is included in appendix A.) For example, the reactants for a rocket combustion process using 3 moles of ammonia ($NH_3$) for fuel and 2 moles of nitric acid ($HNO_3$) for an oxidant are

$$3NH_3+2HNO_3$$

An equivalent formula would be

$$H_{11}N_5O_6$$

where the atoms hydrogen, nitrogen, and oxygen, may be represented by $Z$, $Y$, and $X$, respectively, and 11, 5, and 6 by $a_o$, $b_o$, and $c_o$, respectively. The weight of the equivalent formula $M_r$ can be computed in the usual way and would be 177.128. (If desirable, the quantity of substance in the equivalent formula may be chosen to correspond to a specified value of $M_r$. For example, if $M_r$ is to be one gram, the preceding values would be divided by 177.128.)

The reaction under consideration can be written

$$A(Z_{a_0}Y_{b_0}\ldots)\rightarrow n_1(Z_{a_1}Y_{b_1}\ldots)+n_2(Z_{a_2}Y_{b_2}\ldots)+\ldots+n_i(Z_{a_i}Y_{b_i}\ldots) \tag{1}$$

where $n_i$ is the number of moles of the $i$th molecule or atom. The subscripts $a_i$, $b_i$, . . ., which can take on only positive integral values or zero, denote the number of $Z$, $Y$, . . . atoms in the $i$th molecule. For example, if $Z$, $Y$, and $X$ again represent hydrogen, nitrogen, and oxygen, respectively, the values of $a_i$, $b_i$, and $c_i$ for a water molecule $H_2O$ would be 2, 0, and 1, respectively. It is assumed that the products of reaction are contained by a volume $V$ numerically equal to the gas constant $R$ times the absolute temperature $T$ so that for ideal gases

$$p_i=n_i$$

During the solution of the problem, it is necessary to determine the number of formula weights of the reactants $A$ that are required to balance the reaction given by equation (1). Products of reaction in the gas phase are assumed to be ideal gases that form ideal mixtures and each condensed phase is assumed to have a partial pressure of zero, even when finely divided and suspended in the gas. For solids and liquids therefore

$$p_i=0$$

As an approximation, the following assumptions are also made: Each condensed product is insoluble in all others; the fugacity of each condensed phase is equal to 1 atmosphere; the total volume occupied by the liquids and solids is negligible with respect to the volume occupied by the gases; and the liquid and solid particles have the same temperature and flow velocity as the gases.

**Dissociation equations.**—For simplicity of nomenclature and presentation, the equations for dissociation can be written in terms of the atomic gas as

$$a_iZ+b_iY+\ldots\rightarrow Z_{a_i}Y_{b_i}\ldots \tag{2}$$

The corresponding equation for the equilibrium constant $K_i$ of gaseous molecules is

$$K_i=\frac{p_i}{p_Z^{a_i}\,p_Y^{b_i}\ldots} \tag{3}$$

For liquid or solid molecules, assuming the fugacity of each condensed phase is equal to 1 atmosphere,

$$K_i=\frac{1}{p_Z^{a_i}\,p_Y^{b_i}\ldots} \tag{4}$$

where $p_Z$, $p_Y$, . . . are the partial pressures of the $Z$, $Y$, . . . atoms in equation (1), respectively. The equilibrium constants can also be expressed in terms of the free-energy changes $(\Delta F_T^\circ)_i$ across the dissociation reactions represented by equation (2) or

$$\ln K_i=\left(\frac{-\Delta F_T^\circ}{RT}\right)_i \tag{5}$$

Because the trial composition may not correspond to that at chemical equilibrium, variables $\delta_i$ are conveniently defined so that for gaseous molecules (logarithms to the base 10 are used)

$$\delta_i=\log p_i-a_i\log p_Z-b_i\log p_Y-\ldots-\log K_i \tag{6}$$

and for liquid or solid molecules

$$\delta_i = -a_i \log p_Z - b_i \log p_Y - \ . \ . \ . \ -\log K_i \qquad (7)$$

where $K_i$ is defined by equation (5). The value of each $\delta_i$ must approach zero when the solution to the problem is found. Application of equation (6) or (7) to each product of reaction will result in one equation for each molecule considered since for atoms, $\delta_i$ is identically zero.

**Mass-balance equations.**—A mass-balance equation stating the conservation of atomic type can be written for each chemical element present.

$$a = \frac{1}{A}\sum_i a_i n_i$$

$$b = \frac{1}{A}\sum_i b_i n_i \qquad (8)$$

$$. \ . \ . = . \ . \ .$$

where $a$, $b$, . . . are the number of gram atoms of substance $Z$, $Y$, . . . per equivalent formula required to form the products of reaction. A trial composition generally leads to values of $a$, $b$, . . . that differ from the desired values of $a_o$, $b_o$, . . . but the difference will vanish when the correct composition is found.

**Total-pressure equation.**—The total pressure $P$ is the sum of the partial pressures

$$P = \sum_i p_i \qquad (9)$$

For a process with an assigned pressure, the value of $P$ must approach the assigned value $P_o$ as the solution of the problem is found.

**Constant volume.**—For processes that occur at constant volume, the density of the mixture is constant. The density $\rho$ is defined as

$$\rho = \frac{AM_r}{V} = \frac{AM_r}{RT} \qquad (10)$$

For a reaction process with an assigned density, the value of $\rho$ must approach the assigned value $\rho_o$ as the solution of the problem is found.

## COMBUSTION AT CONSTANT PRESSURE

For given initial conditions, the temperature and the composition following a combustion process are to be found. When chemical energy is included in the enthalpy of each substance, the enthalpy of the products of reaction following an adiabatic combustion must be equal to the enthalpy of the reactants at the initial conditions. An arbitrary base may be adopted for assigning absolute values to the enthalpy of various substances because only differences are measurable. The base used to compute values of enthalpy $H_T^\circ$ was selected to produce positive values for all molecular types entering a combustion process in order to avoid a possible source of difficulty that might occur in the recommended method of adjustment when a logarithm of a negative number (or zero) might be required.

**Enthalpy of fuel and oxidant.**—The enthalpy at initial conditions of the amount of fuel and oxidant corresponding to the equivalent formula $Z_{a_o} Y_{b_o}$ . . . is denoted by $h_o$ and is given by the expression

$$h_o = n_f (H_T^\circ)_f + n_g (H_T^\circ)_g \qquad (11)$$

where $n_f$ and $n_g$ are the number of moles of fuel and oxidant, respectively, corresponding to the equivalent formula $Z_{a_o} Y_{b_o}$ . . . and $(H_T^\circ)_f$ and $(H_T^\circ)_g$ are the molar enthalpies of the fuel and the oxidant, respectively, at the initial conditions. The molar enthalpy $H_T^\circ$ is defined by the equation

$$H_T^\circ = \int_0^T C_p^\circ dT + H_0^\circ$$

where $C_p^\circ$ is the molar specific heat at constant pressure, and $H_0^\circ$ is the chemical energy of the substance at a temperature of 0° $K$. Values of $H_T^\circ$ for several fuels and oxidants are presented with the tables of thermodynamic functions.

**Enthalpy of products of reaction.**—The enthalpy of the products of reaction per equivalent formula can be conveniently represented by a variable $h$ that is given by the equation

$$h = \frac{1}{A}\sum_i (H_T^\circ)_i n_i \qquad (12)$$

When enthalpy is assigned, (for example, with adiabatic combustion) the difference between $h$ and the assigned value $h_o$ must vanish when the correct values of $n_i$, $A$, and $T$ are found. If heat were lost (nonadiabatic combustion), the value of $h_o$ would be accordingly reduced.

**Equations for constant-pressure combustion.**—The equations defining the constant-pressure combustion are:

| Type | Number of equations |
|---|---|
| Dissociative equilibrium | 1 for each molecular type. |
| Conservation of mass | 1 for each chemical element. |
| Constant pressure | 1. |
| Conservation of energy | 1. |

These equations are to be solved simultaneously for the variables $n_i$, $A$, and $T$ ($p_i = n_i$ for gases).

**Correction equations.**—Since the preceding equations are not all linear, it is usually not feasible to find a direct solution. The Newton-Raphson method for solving nonlinear simultaneous equations (reference 5) is well suited to this type of computation. This method can be illustrated by a simple example. If $Q_1$ and $Q_2$ are functions of $q$ and $r$,

$$Q_1 = f_1(q,r)$$

$$Q_2 = f_2(q,r)$$

By taking estimated values, for example $q_o$ and $r_o$, each function may be expanded in a Taylor's series about the point $(q_o,r_o)$ and when derivatives of higher order than the first are neglected

$$\Delta Q_1 = \frac{\partial Q_1}{\partial q}\Delta q + \frac{\partial Q_1}{\partial r}\Delta r$$

$$\Delta Q_2 = \frac{\partial Q_2}{\partial q}\Delta q + \frac{\partial Q_2}{\partial r}\Delta r$$

The desired changes $\Delta Q_1$ and $\Delta Q_2$ can be computed; if the partial derivatives can be numerically evaluated, solving for the approximate changes in $q$ and $r$ to effect simultaneously the desired changes in both $Q_1$ and $Q_2$ is comparatively simple because the equations are linear.

If each of the functions $\delta_i$, $a$, $b$, . . ., $P$, and $h$ given by equations (6) to (9) and (12) is expanded in a Taylor's series about an estimated set of values of the variables and terms involving derivatives of order higher than the first are neglected, the following set of simultaneous linear correction equations results:

For gaseous products

$$x_i - a_i x_Z - b_i x_Y - \ldots - q_i x_T = -\delta_i \tag{13}$$

For solid or liquid products

$$-a_i x_Z - b_i x_Y - \ldots - q_i x_T = -\delta_i \tag{14}$$

For all products

$$\sum_i a_i n_i x_i - A a x_A = \delta_a$$

$$\sum_i b_i n_i x_i - A b x_A = \delta_b \tag{15}$$

$$\ldots - \ldots = \ldots$$

$$\sum_i p_i x_i \qquad = \delta_P \tag{16}$$

$$\sum_i h_i' x_i - A h x_A + T C' x_T = \delta_h \tag{17}$$

where the correction variables and the error parameters may be defined in the logarithmic form

$$x_i = \Delta \log n_i = \Delta \log p_i$$

$$x_Z, x_Y, \ldots = x_i \text{ for atoms}$$

$$x_A = \Delta \log A$$

$$x_T = \Delta \log T$$

$$-\delta_i = \Delta \delta_i$$

$$\delta_a = A a \log \frac{a_o}{a}$$

$$\delta_b = A b \log \frac{b_o}{b}$$

$$\ldots = \ldots$$

$$\delta_P = P \log \frac{P_o}{P}$$

$$\delta_h = A h \log \frac{h_o}{h}$$

and where $q_i = \left(\frac{\Delta H}{RT}\right)_i = \frac{\partial \log K_i}{\partial \log T}$, $h_i' = (H_T^\circ)_i n_i$, $C' = \sum_i (C_p^\circ)_i n_i$

The solution to the set of simultaneous equations relates the value of the $r^{th}$ estimate to the $(r+1)^{th}$ estimate as follows:

$$\log (n_i)_{r+1} = \log (n_i)_r + x_i$$

$$\log (A)_{r+1} = \log (A)_r + x_A$$

$$\log (T)_{r+1} = \log (T)_r + x_T \tag{18}$$

The expansion in the Taylor's series has been carried out in the logarithmic form because this form has been found to result in rapid convergence over a wide range of conditions and avoids the possibility of computing negative partial pressures. If the expansion is carried out in powers of $x_i = \frac{\Delta n_i}{n_i}$ or $x_i = n_i \Delta \left(\frac{1}{n_i}\right)$ the same correction equations result as for the logarithmic variables except for the definitions of the correction variables and error parameters. Quite satisfactory results have been obtained by taking $x_i = \frac{\Delta n_i}{n_i}$ when $x_i$ is positive and $x_i = n_i \Delta \left(\frac{1}{n_i}\right)$ when $x_i$ is negative.

## MATRIX CONSTRUCTION AND REDUCTION

A coefficient matrix is a scheme of detached coefficients of a set of linear equations that are to be solved simultaneously. An augmented matrix is identical to a coefficient matrix except that the constants are included. Equations (13) to (17) constitute such a set of equations for the simultaneous determination of the variables $x_i$, $x_A$, and $x_T$.

**Construction.**—Because of the large number of zeros occurring in the matrix, a considerable saving in effort can be made by proper arrangement of the order of the rows and the columns. The following arrangement provides a partly symmetrical matrix that has been found to be among the easiest to evaluate as long as the products of reaction are principally gaseous and the dissociation constants are expressed in terms of the atomic species:

The order of the columns should be—

(a) $x_i$ of gaseous molecules
(b) $x_i$ of atoms
(c) $x_i$ of liquid and solid products
(d) $x_A$
(e) $x_T$
(f) Constant terms of equations

The order of the rows is—

(a) Dissociation equations in same order as gaseous molecules in columns
(b) Mass-balance equations in order of atoms in columns
(c) Dissociation equations for solid and liquid products in same order as solid and liquid in columns
(d) Total-pressure equation
(e) Heat-balance equation in combustion calculation

The augmented matrix of equations (13) to (17) arranged in this recommended order is shown in figure 1.

| | Equation | Gaseous molecules | | | Atoms | | | Solids or liquids | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $x_1$ | $x_2$ | -- | $x_Z$ | $x_Y$ | -- | -- | $x_N$ | $x_A$ | $x_T$ | Const |
| | (13) | 1 | 0 | 0 | $-a_1$ | $-b_1$ | -- | 0 | 0 | 0 | $-q_1$ | $-\delta_1$ |
| | | 0 | 1 | 0 | $-a_2$ | $-b_2$ | -- | 0 | 0 | 0 | $-q_2$ | $-\delta_2$ |
| | | 0 | 0 | -- | -- | -- | -- | 0 | 0 | 0 | -- | -- |
| a | (15) | $a_1n_1$ | $a_2n_2$ | -- | $n_Z$ | 0 | 0 | -- | $a_Nn_N$ | $-Aa$ | 0 | $\delta_a$ |
| b | | $b_1n_1$ | $b_2n_2$ | -- | 0 | $n_Y$ | 0 | -- | $b_Nn_N$ | $-Ab$ | 0 | $\delta_b$ |
| -- | | -- | -- | -- | 0 | 0 | -- | -- | -- | -- | 0 | -- |
| -- | (14) | 0 | 0 | 0 | -- | -- | -- | 0 | 0 | 0 | -- | -- |
| N | | 0 | 0 | 0 | $a_N$ | $b_N$ | -- | 0 | 0 | 0 | $q_N$ | $\delta_N$ |
| p | (16) | $p_1$ | $p_2$ | -- | $p_Z$ | $p_Y$ | 0 | 0 | 0 | 0 | 0 | $\delta_p$ |
| h | (17) | $h_1'$ | $h_2'$ | -- | $h_Z'$ | $h_Y'$ | -- | -- | $h_N'$ | $-Ah$ | $TC'$ | $\delta_h$ |

FIGURE 1.—General matrix of correction equations for adiabatic combustion at assigned pressure. Equation (13), dissociation of gaseous molecules; equation (15), mass balance; equation (14), dissociation of solids or liquids; equation (16), pressure; equation (17), heat balance.

| | Gaseous molecules | | | Atoms | | | Solids or liquids | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $x_1$ | $x_2$ | -- | $x_Z$ | $x_Y$ | -- | -- | $x_N$ | $x_A$ | $x_T$ | Const |
| a | $a_1n_1$ | $a_2n_2$ | -- | $n_Z$ | 0 | 0 | -- | $a_Nn_N$ | $-Aa$ | 0 | $\delta_a$ |
| b | $b_1n_1$ | $b_2n_2$ | -- | 0 | $n_Y$ | 0 | -- | $b_Nn_N$ | $-Ab$ | 0 | $\delta_b$ |
| -- | -- | -- | -- | 0 | 0 | -- | -- | -- | -- | 0 | -- |
| -- | 0 | 0 | 0 | -- | -- | -- | 0 | 0 | 0 | -- | -- |
| N | 0 | 0 | 0 | $a_N$ | $b_N$ | -- | 0 | 0 | 0 | $q_N$ | $\delta_N$ |
| p | $p_1$ | $p_2$ | -- | $p_Z$ | $p_Y$ | -- | 0 | 0 | 0 | 0 | $\delta_p$ |
| h | $h_1'$ | $h_2'$ | -- | $h_Z'$ | $h_Y'$ | -- | -- | $h_N'$ | $-Ah$ | $TC'$ | $\delta_h$ |

(a) Submatrix $\left[\alpha_2 \vdots \alpha_3\right]$ taken from lower portion of figure 1.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| a | $a_1$ | $a_2$ | -- | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b | $b_1$ | $b_2$ | -- | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| -- | -- | -- | -- | 0 | 0 | -- | 0 | 0 | 0 | 0 | 0 |
| -- | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 | 0 | 0 | 0 |
| N | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| q | $q_1$ | $q_2$ | -- | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| δ | $\delta_1$ | $\delta_2$ | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

(b) Submatrix $\left[\frac{-\alpha_1}{U_k}\right]$ transposed $\left(-\left[\alpha_1\right]\right.$ taken from figure 1).

FIGURE 2.—General form of submatrices of correction equations for adiabatic combustion at assigned pressure.

**Solution.**—One of the best methods of solving simultaneous linear equations is given by Crout (reference 6). With this method, an auxiliary matrix is constructed from an original augmented matrix by a simple routine. This auxiliary matrix is of the order equal to the original matrix. The solution for the set of equations can be obtained by a process of back substitution in the auxiliary matrix.

For convenience, the order of the matrix is reduced before the Crout method is applied. A matrix arranged as recommended can be partitioned so that a unit matrix $[U_m]$ of the order $(m, m)$ appears in the upper left corner, where $m$ is equal to the number of types of gaseous molecule. The original augmented matrix can then be written

$$\left[\begin{array}{c:c} U_m & \alpha_1 \\ \hdashline \alpha_2 & \alpha_3 \end{array}\right] \tag{19}$$

When the Crout method is applied to the original augmented matrix, the Crout auxiliary matrix can be expressed as

$$\left[\begin{array}{c:c} U_m & \alpha_1 \\ \hdashline \alpha_2 & \alpha_4 \end{array}\right] \tag{20}$$

where $[U_m]$, $[\alpha_1]$, and $[\alpha_2]$ are identical to the corresponding submatrices of the original matrix. By observing the operations involved in the construction of the Crout auxiliary matrix, $[\alpha_4]$ is shown to be identical to the auxiliary matrix of the augmented matrix $[\alpha_5]$ defined by

$$[\alpha_5]=[\alpha_3]-[\alpha_2][\alpha_1] \tag{21}$$

For computation, equation (21) is written

$$[\alpha_5]=[\alpha_2 \vdots \alpha_3]\left[\frac{-\alpha_1}{U_k}\right] \tag{22}$$

where $[U_k]$ is a unit matrix of order equal to the number of columns of $[\alpha_1]$. The numerical solution is then obtained by carrying out the matrix multiplication indicated in equation (22) to find $[\alpha_5]$. The Crout auxiliary matrix $[\alpha_4]$ is constructed from $[\alpha_5]$. The values of the variables $x_{m+1}$, . . . , $x_{N+2}$ are found from $[\alpha_4]$ by the process of back substitution given by Crout. The values of the remaining variables are found by the matrix equation

$$\begin{bmatrix} x_1 \\ \cdot \\ \cdot \\ \cdot \\ x_m \end{bmatrix} = -[\alpha_1] \begin{bmatrix} x_{m+1} \\ \cdot \\ \cdot \\ \cdot \\ x_{N+2} \\ -1 \end{bmatrix} \tag{23}$$

For illustration, the submatrices $[\alpha_1]$, $[\alpha_2]$, and $[\alpha_3]$ were taken from figure 1 and used to construct figure 2. The submatrix $[\alpha_2 \vdots \alpha_3]$ corresponds to equations (15), (14), (16), and (17) and is shown in figure 2 (a). The transposed matrix of $\left[\frac{-\alpha_1}{U_k}\right]$ is shown in figure 2 (b); that is, the columns have been tabulated as rows with the first column at the top.

## COMBUSTION AT CONSTANT VOLUME

The procedure given for finding the composition and the temperature of a combustion process at constant pressure can be applied to combustion at constant volume with the following changes:

(a) The correction equation for pressure is replaced by a correction equation for density obtained from equation (10)

$$x_A - x_T = \log \frac{\rho_0}{\rho} \tag{24}$$

(b) The correction equation for conservation of energy must be written in terms of internal energy $E_T^\circ$ and thus becomes

$$\sum_i (E_T^\circ)_i n_i x_i - Ae\, x_A + T\sum_i (C_v^\circ)_i n_i x_T = Ae \log \frac{e_0}{e} \tag{25}$$

where

$$e = \frac{1}{A} \sum_i (E_T^\circ)_i n_i$$

$e_0$ is the assigned internal energy per equivalent formula at initial given conditions, and $C_v^\circ$ is the molar specific heat at constant volume. Substitution of these two equations in the matrix of figures 1 and 2 (a) will permit the composition and the temperature to be found for assigned values of density and internal energy. The application of this method to constant-volume combustion, which, for example, is involved in reciprocating engines and pulse-jet engines, has not been made at the Lewis laboratory.

### ISENTROPIC EXPANSION TO ASSIGNED PRESSURE OR TEMPERATURE

**Assigned pressure.**—The calculation of temperature and equilibrium composition of the products of reaction following isentropic expansion to a fixed pressure involves the simultaneous solution of dissociation, conservation-of-mass, pressure, and entropy-balance equations.

For the reaction of equation (1), the dissociation, conservation of mass, and pressure equations (6) to (9) can again be applied. For the conditions following an isentropic expansion, the entropy $s$ of the products of combustion per equivalent formula after expansion must be equal to the entropy $s_0$ of the products of combustion per equivalent formula before expansion.

$$s_0 = \left\{ \frac{1}{A} \sum_i [n_i (S_T^\circ)_i - Rp_i \ln p_i] \right\}_{\substack{\text{combustion} \\ \text{conditions}}} \tag{26}$$

where $(S_T^\circ)_i$ is the absolute entropy of the product $i$ at standard conditions. This formula is applicable to ideal solids and liquids, assuming $p_i = 0$, as long as their volume is negligible. After the expansion takes place, the entropy per equivalent formula is given by the expression

$$s = \left\{ \frac{1}{A} \sum_i [n_i (S_T^\circ)_i - Rp_i \ln p_i] \right\}_{\text{exit conditions}} \tag{27}$$

Whereas equation (26) is, of course, evaluated at combustion-chamber temperature and pressure, equation (27) is evaluated for exit temperature and pressure. As the solution of the problem is found by successive adjustment of estimated quantities, the value of $s$ approaches $s_0$.

In the adjustment of the values of $n_i$, $A$, and $T$, the correction equations (13) to (16), which have been derived from equations (6) to (9), can be applied. In addition, the following correction equation for entropy can be written from equation (27):

$$\sum s_i' x_i - As\, x_A + C' x_T = \delta_s \tag{28}$$

where

$$\delta_s = As \log \frac{s_0}{s}$$

$$s_i' = (S_T^\circ)_i n_i - Rp_i (1 + \ln p_i)$$

The row matrix of equation (28) shown in figure 3 may be substituted in place of the **h** rows of figures 1 and 2 (a) and the computation carried out as in the combustion calculation.

| | Equation |
|---|---|
| **s** | (28) |

$$\left[ \begin{array}{ccc|cccccc} s_1' & s_2' & \cdots & s_X' & s_Y' & \cdots & \cdots & s_N' & -As \quad C' \quad \delta_s \end{array} \right]$$

FIGURE 3.—Row matrix to be substituted in place of **h** row in figure 1 and in figure 2 (a) for isentropic expansion to assigned pressure. Equation (28), entropy balance.

**Assigned temperature.**—For the computation of data for enthalpy-entropy diagrams and for other practical computations, it is often necessary to find the exit pressure and composition as a function of exit temperature. The procedure required is the same as that described for isentropic expansion to an assigned pressure except that, in addition to substituting the **s** row in place of the **h** row, the pressure equation (**p** row) and the temperature column ($x_T$) are dropped from the matrix of figure 1; accordingly, the **p** row and $x_T$ column are dropped from figure 2 (a) and the **q** row from figure 2 (b).

### ISENTROPIC EXPANSION TO LOCAL VELOCITY OF SOUND

The theoretical velocity of sound that includes the effect of dissociation can be computed at any point in a nozzle with a modification of the matrix previously derived to obtain the correction quantities.

**Velocity of sound.**—The velocity of sound $u$ can be defined as

$$u^2 = \left( \frac{\partial P}{\partial \rho} \right)_s \tag{29}$$

where the subscript $s$ denotes the condition of constant entropy. The total differential of pressure $dP$ can be found from equation (9).

$$dP = \sum_i dp_i \tag{30}$$

and the total differential of density $d\rho$ can be found from equation (10).

$$d\rho = \frac{M_r}{RT} dA - \frac{AM_r}{RT^2} dT \tag{31}$$

Then

$$\frac{dP}{d\rho} = \frac{\sum_i dp_i}{\frac{M_r}{RT} dA - \frac{AM_r}{RT^2} dT} = \frac{\sum_i p_i \frac{d \log p_i}{d \log T}}{\frac{AM_r}{RT} \left( \frac{d \log A}{d \log T} - 1 \right)}$$

Therefore

$$u^2 = \left( \frac{\partial P}{\partial \rho} \right)_s = \frac{RT \sum_i p_i D_i}{AM_r (D_A - 1)} \tag{32}$$

where

$$D_i=\left(\frac{\partial \log n_i}{\partial \log T}\right)_s$$

$$D_A=\left(\frac{\partial \log A}{\partial \log T}\right)_s$$

This expression will permit evaluation of $u^2$, provided the values of the partial derivatives $D_i$ and $D_A$ are found for conditions of chemical equilibrium and for an isentropic process. If the value of $T$ is in degrees Kelvin and $p_i$ in atmospheres the value of $8.3144\times10^7$ for $R$ will give $u$ in centimeters per second. The conditions of chemical equilibrium and constant entropy are introduced by writing the total differentials of equations (6) to (8) and (27). The total differential of these equations expressed in logarithmic variables and divided by $d \log T$ can be written, for gaseous products,

$$\frac{d \log p_i}{d \log T}-a_i\frac{d \log p_Z}{d \log T}-b_i\frac{d \log p_Y}{d \log T}-\ldots-q_i=\frac{d\delta_i}{d \log T} \qquad (33)$$

for liquid and solid products,

$$-a_i\frac{d \log p_Z}{d \log T}-b_i\frac{d \log p_Y}{d \log T}-\ldots-q_i=\frac{d\delta_i}{d \log T} \qquad (34)$$

and for all products of reaction,

$$\begin{aligned}
&\sum_i a_i n_i\frac{d \log n_i}{d \log T}-Aa\frac{d \log A}{d \log T}=Aa\frac{d \log a}{d \log T}\\
&\sum_i b_i n_i\frac{d \log n_i}{d \log T}-Ab\frac{d \log A}{d \log T}=Ab\frac{d \log b}{d \log T}\\
&\qquad\ldots-\ldots=\ldots
\end{aligned} \qquad (35)$$

$$\sum_i s_i'\frac{d \log n_i}{d \log T}-As\frac{d \log A}{d \log T}+C'=As\frac{d \log s}{d \log T} \qquad (36)$$

If $d \log s$ is taken as 0, $s$ is a constant; if $d \log a$, $d \log b$, . . ., and $d\delta_i$ are taken as 0, mass is constant, atomic types are conserved, and rate of change in composition corresponds to constant values of $\delta_i$. With these assumptions the partial derivatives $D_i$ and $D_A$ may be substituted for the total derivatives in equations (33) to (36). The augmented matrix formed from these equations may be partitioned in a manner similar to the combustion matrix. The resulting submatrices are shown in figure 4 with the sign reversed. When $D_i$ and $D_A$ are determined by means of the matrices shown in figure 4, the velocity of sound can be calculated from equation (32). This equation can be applied to mixtures of liquid and solid products in equilibrium as long as their volume is negligible compared with the volume of the gas mixture and provided the liquid and solid particles move in velocity and temperature equilibrium with the gas.

**Specific heat.**—The molar specific heat at constant pressure of a mixture in equilibrium may be found from equation (12) as follows:

$$C_p^\circ=\frac{A}{n}\left(\frac{\partial h}{\partial T}\right)_P=\frac{1}{nT}\left[\sum_i (H_T^\circ)_i n_i\left(\frac{\partial \log n_i}{\partial \log T}\right)_P-Ah\left(\frac{\partial \log A}{\partial \log T}\right)_P+TC'\right] \qquad (37)$$

$$\begin{array}{c} \\ \begin{array}{c} \mathbf{a}\\ \mathbf{b}\\ \cdots\\ \cdots\\ \mathbf{N}\\ \mathbf{s} \end{array} \end{array}
\begin{array}{c}
\begin{array}{ccccccccc} -D_1 & -D_2 & \cdots & -D_Z & -D_Y & \cdots & \cdots & -D_N & -D_A \end{array}\\
\left[\begin{array}{ccc:ccccccc}
a_1n_1 & a_2n_2 & \cdots & 0 & 0 & 0 & 0 & a_Nn_N & -Aa & 0\\
b_1n_1 & b_2n_2 & \cdots & 0 & 0 & 0 & 0 & b_Nn_N & -Ab & 0\\
\cdots & \cdots & \cdots & 0 & 0 & 0 & 0 & \cdots & \cdots & 0\\
0 & 0 & 0 & \cdots & \cdots & \cdots & 0 & 0 & 0 & \cdots\\
0 & 0 & 0 & a_N & b_N & \cdots & 0 & 0 & 0 & q_N\\
s_1' & s_2' & \cdots & s_Z' & s_Y' & \cdots & 0 & s_N' & -As & C'
\end{array}\right]
\end{array}$$

(a) Submatrix $\left[\alpha_2 \vdots \alpha_3\right]$.

$$\begin{array}{c} \mathbf{a}\\ \mathbf{b}\\ \cdots\\ \cdots\\ \mathbf{N}\\ \\ \mathbf{q} \end{array}
\left[\begin{array}{ccc:ccccccc}
a_1 & a_2 & \cdots & 1 & 0 & 0 & 0 & 0 & 0 & 0\\
b_1 & b_2 & \cdots & 0 & 1 & 0 & 0 & 0 & 0 & 0\\
\cdots & \cdots & \cdots & 0 & 0 & \cdots & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0\\
q_1 & q_2 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{array}\right]$$

(b) Submatrix $\left[\frac{-\alpha_1}{C_k}\right]$ transposed.

FIGURE 4.—General form of submatrices of equations for partial derivatives at constant entropy.

where $n=\sum_i n_i$. Equation (30) can be written as

$$\sum_i p_i\frac{d \log n_i}{d \log T}=\frac{P\,d \log P}{d \log T} \qquad (38)$$

If $d \log P$ is taken as 0, the pressure is constant; therefore, when equation (38) is substituted in the matrix of figure 4 in place of equation (36), the values of $\left(\frac{\partial \log n_i}{\partial \log T}\right)_P$ and $\left(\frac{\partial \log A}{\partial \log T}\right)_P$ can be found. These values can then be substituted in equation (37) to evaluate $C_p^\circ$.

**Isentropic expansion to assigned Mach number.**—According to the law of conservation of energy the sum of the enthalpy and the kinetic energy of a certain quantity of gas at any point in a nozzle is constant. If this sum per equivalent formula at any point $l$ is denoted by a parameter $h^*$, then

$$h^*=\left[h+\frac{1}{2}M_r v^2/J\right]_l \qquad (39)$$

where $v$ is the velocity of flow of the gas, $J$ is a dimensional constant, and the subscript $l$ indicates that the variables are evaluated at point $l$ in the nozzle. The Mach number $M$ of the flow is

$$M=\frac{v}{u} \qquad (40)$$

Equations (32), (39), and (40) may be combined to give

$$h^*=\frac{\sum_i (H_T^\circ)_i n_i}{A}+\frac{M^2RT\sum_i p_iD_i}{2A(D_A-1)} \qquad (41)$$

where the value of $R$ becomes 1.98718 (cal/(mole) (°K)). As the solution of the problem is found by successive adjustments of the estimated quantities, $h^*$ approaches $h_o$.

If equation (41) is expanded in a manner similar to that used to obtain equation (17) and if the differentials of derivatives are assumed to be negligible, the correction equation becomes

$$\sum_i h_i'' x_i - Ah^* x_A + TC'' x_T = \delta_h^* \qquad (42)$$

where

$$h_i'' = h_i' + \frac{M^2 RT p_i D_i}{2(D_A - 1)}$$

$$\delta_h^* = Ah^* \log \frac{h_o}{h^*}$$

$$C'' = \sum_i \left[ n_i (C_p^\circ)_i + \frac{M^2 R p_i D_i}{2(D_A - 1)} \right]$$

Equation (42), together with equations (13) to (15) and (28), constitute the correction equations for the isentropic expansion to an assigned Mach number. The coefficients of these equations form the submatrices shown in figure 5.

In order to carry out the numerical computations, values of $n_i$, $A$, and $T$ are estimated for the assigned conditions; the values of $D_i$ and $D_A$ are obtained by means of the submatrices of figure 4, and used to compute the numerical values of the elements of the bottom row of figure 5(a). The submatrices of figure 5 are then used to compute the values of the corrections to $n_i$, $A$, and $T$. This process can be repeated until the assigned conditions are satisfied.

| | $x_1$ | $x_2$ | ----- | $x_Z$ | $x_Y$ | --- | --- | $x_N$ | $x_A$ | $x_T$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| a | $a_1n_1$ | $a_2n_2$ | ----- | $n_Z$ | 0 | 0 | ___ | $a_Nn_N$ | $-Aa$ | 0 | $\delta_a$ |
| b | $b_1n_1$ | $b_2n_2$ | ----- | 0 | $n_Y$ | 0 | ---- | $b_Nn_N$ | $-Ab$ | 0 | $\delta_b$ |
| ------ | ----- | ----- | ----- | 0 | 0 | ___ | ___ | ----- | ----- | 0 | ___ |
| ------ | 0 | 0 | 0 | ----- | ----- | ---- | 0 | 0 | 0 | ----- | ___ |
| N | 0 | 0 | 0 | $a_N$ | $b_N$ | ---- | 0 | 0 | 0 | $q_N$ | $\delta_N$ |
| s | $s_1'$ | $s_2'$ | ----- | $s_Z'$ | $s_Y'$ | ---- | ---- | $s_N'$ | $-As$ | $C'$ | $\delta_s$ |
| h* | $h_1''$ | $h_2''$ | ----- | $h_Z''$ | $h_Y''$ | ---- | ---- | $h_N''$ | $-Ah^*$ | $TC''$ | $\delta_{h^*}$ |

(a) Submatrix $\left[\alpha_2 \vdots \alpha_2\right]$.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| a | $a_1$ | $a_2$ | ----- | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b | $b_1$ | $b_2$ | ----- | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ------ | ----- | ----- | ----- | 0 | 0 | ---- | 0 | 0 | 0 | 0 | 0 |
| ------ | 0 | 0 | 0 | 0 | 0 | 0 | ___ | 0 | 0 | 0 | 0 |
| N | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| q | $q_1$ | $q_2$ | ----- | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| δ | $\delta_1$ | $\delta_2$ | ----- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

(b) Submatrix $\left[\frac{-\alpha_1}{U_k}\right]$ transposed.

FIGURE 5.—General form of submatrices of correction equations for isentropic expansion to assigned Mach number.

**Throat area of supersonic nozzle.**—The process of isentropic expansion to a local Mach number of 1 is particularly interesting in the determination of the throat area of a nozzle having greater than critical pressure ratio. By assuming that the flow is isentropic and that chemical equilibrium is maintained throughout the expansion process, the flow velocity $v$ at the throat must be equal to the velocity of sound $u$ at the throat. The values $n_i$, $A$, $T$, and $u$ can be found for a Mach number of 1 by use of the procedure given.

The throat area $t$ can be calculated from the equation

$$\frac{t}{m} = \frac{RT}{AM_r u} \qquad (43)$$

where $m$ is the mass flow per second. If $T$ is in degrees Kelvin and $u$ is in centimeters per second, $R$ equal to 82.0567 $\frac{(\text{cm}^3)\ (\text{atm})}{(\text{°K})\ (\text{mole})}$ will give $t/m$ in (cm$^2$) (sec)/(gm). This equation can be applied to mixtures of liquid or solid phases in equilibrium provided that the volume occupied by the liquid and the solid phases is negligible compared with that of the gas phase and that the particles of liquid and solid are in thermal and velocity equilibrium with the gas phase.

## EXAMPLE OF COMBUSTION OF DIBORANE WITH OXYGEN BIFLUORIDE

The calculation of equilibrium temperature and composition of the reaction of 1 mole of diborane ($B_2H_6$) with 5 moles of oxygen bifluoride ($OF_2$) is illustrated in this example for processes of

(a) constant-pressure adiabatic combustion
(b) isentropic expansion to 1 atmosphere
(c) isentropic expansion to the local velocity of sound

An equivalent formula of these reactants is

$$Z_{a_0} Y_{b_0} X_{c_0} W_{d_0} = H_6B_2F_{10}O_5$$

and $a_0=6$, $b_0=2$, $c_0=10$, and $d_0=5$.

The following gaseous products will be considered as the products of reaction: boron trifluoride $BF_3$, boron trioxide $B_2O_3$, boron fluoride BF, boron hydride BH, boron oxide BO, diatomic boron $B_2$, hydrogen $H_2$, water vapor $H_2O$, hydroxyl radical OH, hydrogen fluoride HF, oxygen $O_2$, fluorine $F_2$, atomic hydrogen H, atomic boron B, atomic fluorine F, and atomic oxygen O. No liquids or solids are included. If the products are numbered in the order given, they can be identified in the terminology of equation (1) as follows:

$$BF_3 = H_0B_1F_3O_0$$

and therefore

$$a_1=0,\ b_1=1,\ c_1=3, \text{ and } d_1=0$$

Similarly,

$$B_2O_3 = H_0B_2F_0O_3$$

and

$$a_2=0,\ b_2=2,\ c_2=0, \text{ and } d_2=3$$

All values of $a_t$, $b_t$, $c_t$, and $d_t$ for this problem, together with the thermodynamic properties used, are listed in table I. Although these thermodynamic values and the enthalpies of $B_2H_6$ and of $OF_2$ have since been revised, and therefore do not correspond to the values listed in the thermodynamic tables presented in a later section, they are adequate for the purpose of this example. The enthalpy values used are

$$(H^{\circ}_{298.16})_{\text{liquid } B_2H_6}=570.149 \text{ kilocalories per mole}$$

$$(H^{\circ}_{128.3})_{\text{liquid } OF_2}=67.077 \text{ kilocalories per mole}$$

The enthalpy of the amount of fuel and oxidant at initial conditions corresponding to the equivalent formula is, from equation (11),

$$h_o=570.149+5(67.077)=905.534 \frac{\text{kilocalories}}{\text{equivalent formula}} \tag{44}$$

The values of $a_t$, $b_t$, $c_t$, $d_t$, and $h_o$ are constant for all parts of this example.

### COMBUSTION PROCESS

The adiabatic combustion process was assumed to occur at a constant pressure of 20.4 atmospheres.

**First estimate.**—From previous computations or from simple calculations with equilibrium constants, estimating reasonable values for the composition and the temperature is usually possible. This procedure is recommended inasmuch as close estimates reduce the number of trials that must be made. In order to show that an arbitrary composition which is not based on probable final values of the composition can be used, however, the first estimates for this example for $n_t$ and $A$ have been taken equal to 1 mole and a temperature of 4000° K. The possibility of divergence is discussed in a later section. All estimated quantities will be used with three decimal places to distinguish them from numbers that are always integers.

**Evaluation of submatrices.**—The numerical values of the elements of the submatrices shown in figures 2(a) and 2(b) can now be computed and are shown in figure 6. The steps are as follows:

1. The values of $a_t$, $b_t$, $c_t$ and $d_t$ are entered in rows **a, b, c**, and **d** of figure 6(b) and a 1 is entered on each square of the diagonal of $[U_k]$ according to figure 2(b).

2. Values of $q_t=\left(\frac{\Delta H}{RT}\right)_t$ from tables of thermodynamic functions are entered in row **q** of figure 6(*b*). In this case they are obtained from table I.

3. The values of the elements of the $\delta$ row of figure 6 (b) may be computed from equation (6) for gaseous products

$$\delta_t=\log p_t-a_t \log p_{\mathrm{H}}-b_t \log p_{\mathrm{B}}-c_t \log p_{\mathrm{F}}-d_t \log p_{\mathrm{O}}-\log K_t$$

The values of $\log K_t$ are obtained from tables of thermodynamic properties, in this case table I. Because all molecules and atoms are estimated to be 1, their logarithms are 0 so that in this case

$$\delta_t=-\log K_t$$

4. The estimated values of $n_t$ are entered in row **p** of figure 6 (a). In case liquids or solids are present their value will be zero.

| | Gaseous molecules | | | | | | | | | | | | Atoms | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $x_{BF_3}$ | $x_{B_2O_3}$ | $x_{BF}$ | $x_{BH}$ | $x_{BO}$ | $x_{B_2}$ | $x_{H_2}$ | $x_{H_2O}$ | $x_{OH}$ | $x_{HF}$ | $x_{O_2}$ | $x_{F_2}$ | $x_H$ | $x_B$ | $x_F$ | $x_O$ | $x_A$ | $x_T$ | Const |
| **a** | 0 | 0 | 0 | 1.000 | 0 | 0 | 2.000 | 2.000 | 1.000 | 1.000 | 0 | 0 | 1.000 | 0 | 0 | 0 | −8.000 | 0 | −0.999 |
| **b** | 1.000 | 2.000 | 1.000 | 1.000 | 1.000 | 2.000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | −9.000 | 0 | −5.879 |
| **c** | 3.000 | 0 | 1.000 | 0 | 0 | 0 | 0 | 0 | 0 | 1.000 | 0 | 2.000 | 0 | 0 | 1.000 | 0 | −8.000 | 0 | 0.775 |
| **d** | 0 | 3.000 | 0 | 0 | 1.000 | 0 | 0 | 1.000 | 1.000 | 0 | 2.000 | 0 | 0 | 0 | 0 | 1.000 | −9.000 | 0 | −2.297 |
| **p** | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0 | 0 | 1.688 |
| **h** | .721 | 2.334 | 2.629 | 3.569 | 2.527 | 5.720 | .995 | .577 | .765 | .820 | .378 | .960 | 1.051 | 3.177 | .826 | .794 | −27.346 | 6.446 | −13.125 |

(a) Submatrix $\left[\alpha_2 \vdots \alpha_3\right]$.

| | $x_{BF_3}$ | $x_{B_2O_3}$ | $x_{BF}$ | $x_{BH}$ | $x_{BO}$ | $x_{B_2}$ | $x_{H_2}$ | $x_{H_2O}$ | $x_{OH}$ | $x_{HF}$ | $x_{O_2}$ | $x_{F_2}$ | $x_H$ | $x_B$ | $x_F$ | $x_O$ | $x_A$ | $x_T$ | Const |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **a** | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **b** | 1 | 2 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **c** | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **d** | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| **q** | −62.075 | −80.593 | −17.288 | −8.300 | −18.183 | −7.969 | −13.939 | −29.209 | −13.603 | −19.674 | −15.313 | −8.705 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| **δ** | −5.695 | −5.109 | −1.634 | 2.611 | −1.033 | 2.763 | 0.406 | 0.347 | 0.167 | −1.894 | 0.380 | 3.137 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

(b) Submatrix $\left[\frac{-\alpha_t}{U_k}\right]$ transposed.

FIGURE 6.—Numerical example of submatrices of correction equations for adiabatic combustion of diborane and oxygen bifluoride after first estimate of $n_t$, $A$, and $T$.

5. The values of the elements in rows **a**, **b**, **c**, and **d** of figure 6 (a), except columns $x_A$, $x_T$, and constant, are obtained by multiplying the value of $n_i$ by the value of the corresponding element of the respective row in figure 6 (b). For example, the entries in the first column are $0\times1.000=0$, $1\times1.000=1.000$, $3\times1.000=3.000$ and $0\times1.000=0$.

6. Values of the elements of row **h** of figure 6 (a), except columns $x_A$, $x_T$, and constant, are obtained by multiplying the value of $n_i$ by the value of $(H^\circ_T)_i$ from tables of thermodynamic functions, in this case table I. For example, the entry in the first column is $72{,}172\times1.000=72{,}172$. All values in row **h** have been divided by $10^5$.

7. The values of the elements of column $x_A$ figure 6 (a) are obtained by summing elements to the left in each row and writing the negative of the total in column $x_A$ except for row **p** where the value is zero.

8. The value of the $x_T$ column (fig. 6 (a)) is zero except for the **h** row where the value is $T\sum_i (C^\circ_p)_i n_i$. The values of $(C^\circ_p)_i$ are obtained from tables of thermodynamic functions, in this case table I.

9. Values of the constant column for figure 6 (a) for all rows except row **p** are found as follows: The value already entered in the $x_A$ column for row **a** is $-Aa$. With the estimated value of $A=1.000$

$$a=\frac{Aa}{A}=\frac{8.000}{1.000}=8.000$$

$$\delta_a=Aa\log\frac{a_0}{a}$$

$$=8.000\log\frac{6}{8.000}=-0.999$$

the values of $\delta_b$, $\delta_c$, $\delta_d$, and $\delta_h$ are found in a similar manner.

| $x_H$ | $x_B$ | $x_F$ | $x_O$ | $x_A$ | $x_T$ | Const |
|---|---|---|---|---|---|---|
| 12.000 | 1.000 | 1.000 | 3.000 | −8.000 | −127.878 | 1.391 |
| 1.000 | 13.000 | 4.000 | 7.000 | −9.000 | −283.010 | −16.322 |
| 1.000 | 4.000 | 16.000 | 0 | −8.000 | −240.597 | −18.564 |
| 3.000 | 7.000 | 0 | 17.000 | −9.000 | −333.400 | −17.383 |
| 8.000 | 9.000 | 8.000 | 9.000 | 0 | −294.871 | −3.866 |
| 8.854 | 28.736 | 7.861 | 12.414 | −27.346 | −454.757 | −7.663 |

(a) Matrix $[\alpha_6]$ obtained from matrix multiplication $[\alpha_2 \vdots \alpha_3]\left[\frac{-\alpha_1}{U_k}\right]$.

| | | | | | | |
|---|---|---|---|---|---|---|
| 12.000 | 0.08333 | 0.08333 | 0.2500 | −0.6667 | −10.656 | 0.1159 |
| 1.000 | 12.917 | 0.3032 | 0.5226 | −0.6451 | −21.085 | −1.273 |
| 1.000 | 3.917 | 14.729 | −0.1560 | −0.3263 | −10.004 | −0.5902 |
| 3.000 | 6.750 | −2.297 | 12.364 | −0.2745 | −14.727 | −0.8487 |
| 8.000 | 8.333 | 4.807 | 3.395 | 13.210 | −4.857 | 0.8731 |
| 8.854 | 27.998 | −1.366 | −4.644 | −5.102 | 172 652 | 0.1544 |

(b) Matrix $[\alpha_7]$ (Crout's auxiliary matrix of $[\alpha_6]$).

| $x_H$ | $x_B$ | $x_F$ | $x_O$ | $x_A$ | $x_T$ |
|---|---|---|---|---|---|
| 1.299 | 0.9290 | 1.222 | 1.459 | 0.1232 | 0.1544 |

(c) Values of corrections (Crout's final matrix).

FIGURE 7. Numerical example of the solution of correction equations by matrix methods.

10. The constant column of row **p** is found as follows: The sum of the elements of row **p** is the pressure $P=16.000$; $\delta_P$ is computed from the formula

$$\delta_P=P\log\frac{P_o}{P}$$

$$\delta_P=16.000\log\frac{20.4}{16.000}=1.688$$

The matrix multiplication $[\alpha_2 \vdots \alpha_3]\left[\frac{-\alpha_1}{U_k}\right]$ will result in the matrix $[\alpha_6]$ shown in figure 7 (a). The steps of this multiplication are shown in standard textbooks such as reference 7. Crout's auxiliary matrix corresponding to $[\alpha_6]$ may then be constructed and is shown in figure 7 (b) and the values of $x_H$, $x_B$, $x_F$, $x_O$, $x_A$, and $x_T$ are shown in figure 7 (c). The values of the remaining functions are computed with the aid of equation (23). The solution is found to be

| | |
|---|---|
| $x_{BF_3}=0.7056$ | $x_{OH}=0.4907$ |
| $x_{B_2O_3}=-1.100$ | $x_{HF}=1.377$ |
| $x_{BF}=1.116$ | $x_{O_2}=0.1737$ |
| $x_{BH}=1.665$ | $x_{F_2}=-2.037$ |
| $x_{BO}=0.6135$ | $x_H=1.299$ |
| $x_{B_2}=-2.139$ | $x_B=0.9290$ |
| $x_{H_2}=0.03982$ | $x_F=1.222$ |
| $x_{H_2O}=-0.7999$ | $x_O=1.459$ |
| $x_A=0.1232$ | $x_T=0.1544$ |

These values are to be applied to the initial estimates for $n_i$, $A$, and $T$ according to the equation

$$(\log n_i)_{\substack{\text{second}\\\text{estimate}}}=(\log n_i)_{\substack{\text{first}\\\text{estimate}}}+x_i \tag{45}$$

For example, the second estimate of $n_{BF_3}$ would be

$$(\log n_{BF_3})_{\substack{\text{second}\\\text{estimate}}}=\log 1.000+0.7056$$

$$(n_{BF_3})_{\substack{\text{second}\\\text{estimate}}}=5.077$$

The second estimates of $n_i$, $A$, and $T$ are then used to set up new submatrices according to the procedure described. The process is repeated until the desired accuracy has been obtained. For this example, six approximations were required to give the following final values of $n_i$, $A$, and $T$:

| | |
|---|---|
| $n_{BF_3}=2.6593$ | $n_{OH}=0.6785$ |
| $n_{B_2O_3}=0.1235$ | $n_{HF}=7.1456$ |
| $n_{BF}=0.1936$ | $n_{O_2}=0.9210$ |
| $n_{BH}=0.0001$ | $n_{F_2}=0.0003$ |
| $n_{BO}=0.1669$ | $n_H=1.7694$ |
| $n_{B_2}=0$ | $n_B=0.0577$ |
| $n_{H_2}=0.1271$ | $n_F=1.3043$ |
| $n_{H_2O}=0.0627$ | $n_O=5.1903$ |
| $A=1.6622$ | $T=4775.5^\circ$ K |

**Discussion of convergence.**—In order to demonstrate the convergence of the process with large errors in the first estimate, the example of the combustion of diborane and fluorine oxide was solved by using 1 mole of each product, a value of 1 for $A$, and a temperature of 4000° K for the first estimate. Because these first estimates were made without regard for the probable final values, large errors were present in the second approximation and six approximations were required to eliminate the error. The convergence is shown in terms of the parameters $a$, $b$, $c$, $d$, $P$, $h$, and $\epsilon$ in the following table where $\epsilon$ is defined as

$$\epsilon=\sum_i \left|\log k_i\right|+\left|\log \frac{a_o}{a}\right|+\left|\log \frac{b_o}{b}\right|+\left|\log \frac{c_o}{c}\right|+\left|\log \frac{d_o}{d}\right|+\left|\log \frac{P_o}{P}\right|+\left|\log \frac{h_o}{h}\right|$$

RESULTS OF APPROXIMATIONS

| Parameter | First estimate | Trial number | | | | | | Desired value |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | |
| $a$ | 8 | 36.840 | 7.005 | 6.286 | 6.079 | 6.002 | 6.000 | 6.000 |
| $b$ | 9 | 23.346 | 11.605 | 2.653 | 2.325 | 2.008 | 2.000 | 2.000 |
| $c$ | 8 | 51.540 | 24.082 | 13.104 | 10.541 | 10.016 | 10.000 | 10.000 |
| $d$ | 9 | 29.641 | 11.954 | 33.660 | 5.240 | 5.022 | 5.000 | 5.000 |
| $P$ | 16 | 125.485 | 38.000 | 52.434 | 21.416 | 20.436 | 20.400 | 20.400 |
| $h$ | 2734.615 | 12,055.015 | 2090.090 | 2909.950 | 965.968 | 912.368 | 905.594 | 905.534 |
| $\epsilon$ | 26.892 | 5.861 | 4.092 | 2.505 | .537 | .011 | .002 | 0 |

This method has been used in routine computation for several years without encountering a divergent case in a practical problem. At least for special cases when temperature is assigned, the process will converge for all values of the first estimates. Divergence is known to occur for certain cases where temperature is used as a variable when the first estimate of temperature and composition is sufficiently in error. Although no mathematical analysis has been made to determine the theoretical limits of convergence, the process appears to be satisfactory for practical computation.

Special treatment would be required if divergence is encountered. Obtaining convergence should be possible by a sufficiently close new estimate of composition and temperature. This procedure is recommended when it is feasible but other procedures can be devised, depending on the individual case.

### ISENTROPIC EXPANSION TO FIXED PRESSURE

The temperature and the composition of the products of reaction following an isentropic-expansion ratio of 20.4 at chemical equilibrium were also computed for the products of reaction of this example. The value of $s_o$ is found from equation (26) by using the final values of each constituent of the adiabatic combustion and the absolute entropy values corresponding to the final combustion temperature. The calculated value of $s_o$ was 763.476 calories per °K per mole.

**First estimates.**—The number of approximations necessary for a complete calculation can be considerably reduced if the initial estimate is based on previous experience. The final values of $n_i$ and $A$ determined for the combustion process of this example can therefore be the basis for this first estimate.

Because the expansion ratio is 20.4, the four largest components can be estimated to be 1/20.4 of their combustion value.

$$n_{BF_3}=0.1304$$
$$n_{HF}=0.3503$$
$$n_{H}=0.0867$$
$$n_{O}=0.2544$$
$$A=0.0815$$

For convenience of presentation, the temperature was estimated to be 4000° K so that the values of table I could be used again. The remaining products can be estimated from the dissociation equations by setting $\log k_i=0$. For example, $p_F$ would be determined with the assumed values of $p_{HF}$ and $p_H$ from equation (6) and table I ($p_i=n_i$)

$$0=\log 0.3503-\log 0.0867-\log p_F-1.8944$$
$$\log p_F=-0.45556+1.06198-1.8944$$
$$=-1.28798$$
$$p_F=0.0515$$

Similarly, $p_B$ can be estimated with the assumed values of $p_{BF_3}$ and $p_F$

$$0=\log 0.1304-\log p_B-3\log 0.0515-5.6953$$
$$\log p_B=-0.88472+3.86394-5.6953$$
$$p_B=0.0019$$

If this procedure is followed for all the remaining constituents, the following list of first estimates can be made:

$$\begin{array}{rr}
n_{BF_3}=0.1304 & n_{OH}=0.0150\\
n_{B_2O_3}=0.0078 & n_{HF}=0.3503\\
n_{BF}=0.0043 & n_{O_2}=0.0269\\
n_{BH}=0 & n_{F_2}=0\\
n_{BO}=0.0053 & n_{H}=0.0867\\
n_{B_2}=0 & n_{B}=0.0019\\
n_{H_2}=0.0029 & n_{F}=0.0515\\
n_{H_2O}=0.0009 & n_{O}=0.2544\\
A=0.0815 & T=4000^\circ\ \mathrm{K}
\end{array}$$

**Construction of submatrices.**—The construction of the submatrices may now be carried out and is shown in figure 8. The steps are the same as for the combustion example except for steps 6 to 9, which are different because the enthalpy equation has been replaced with the entropy equation.

The values of the elements of row **s** of figure 8(a) are obtained from the expression

$$s_i'=n_i[(S_T^\circ)_i-1.98718-4.57565\log p_i]$$

The values of $(S_T^\circ)_i$ are obtained from tables of thermodynamic data, in this case table I. For example, the entry in the first column is computed to be

$$(s_{BF_3})'=0.1304\ (105.951-1.98718-4.57565\log 0.1304)$$
$$=14.0848$$

7. The values of the entries in the $x_A$ column of figure 8(a) are obtained in the same manner as for figure 6(a) except for the **s** row where the sum of the elements of the **p** row times 1.98718 is added to the sum of the elements of the **s** row and entered in column $x_A$.

8. The value of the entries in the $x_T$ column is zero except for the **s** row where it is $\sum_i n_i(C_p^\circ)_i$. The values of $(C_p^\circ)_i$ are obtained from tables of thermodynamic data, in this case table I.

9. The value of $\delta_s$ is found in a manner similar to $\delta_a$.

### ISENTROPIC EXPANSION TO MACH NUMBER OF 1

The temperature and the composition of the products of reaction following an isentropic expansion to the local velocity of sound was computed for the products of reaction considered in this example, assuming chemical equilibrium. The value of $s_o$ is the same as that found for the isentropic expansion to 1 atmosphere.

**First estimate.**—For simplicity, the same first estimates of 1 mole, 1, and 4000° K, for $n_i$, $A$, and $T$, respectively, were again made.

**Construction of submatrices.**—The submatrices corresponding to figure 5 may be constructed and are shown in figure 9.

The submatrices corresponding to figure 4 are first constructed. The steps are the same as for figure 8 except that row **p** and the constant column are omitted. The matrix multiplication may then be carried out and the values of the partial derivatives $D_i$ and $D_A$ computed in a manner similar to the computation in the combustion example. These values of $D_i$ and $D_A$ together with $(H_T^\circ)_i$ are used to calculate the elements of row **h*** of figure 9(a) except columns $x_A$, $x_T$, and constant. For example, when the values of $D_{BF_3}=12.990$ and $D_A=19.039$ are used, the value of

$$(h_{BF_3})''=(h_{BF_3})'+\frac{M^2RTp_{BF_3}D_{BF_3}}{2(D_A-1)} \text{ becomes } 75{,}034=72{,}172+\frac{1\times1.98718\times4000\times1.000\times12.990}{2(19.039-1)} \text{ (cal)}$$

All values in row **h*** have been divided by $10^5$.

The value of the element in row **h***, column $x_A$ is the sum of the elements to the left. The element in row **h***, column $x_T$ is given by

$$TC''=T\sum_i\left[n_i(C_p^\circ)_i+\frac{M^2Rp_iD_i}{2(D_A-1)}\right]$$

and the value of the constant column is obtained as in the previous examples. Matrix multiplication that was carried out for the determination of $D_i$ and $D_A$ values may now be extended by an additional row and column and the value of $x_i$, $x_A$, and $x_T$ found as in the previous examples. These values may then be used to obtain the second estimates for $n_i$, $A$, and $T$ and the computation repeated until the desired accuracy has been obtained.

| | Gaseous molecules | | | | | | | | | | | | Atoms | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $x_{BF_3}$ | $x_{B_2O_3}$ | $x_{BF}$ | $x_{BH}$ | $x_{BO}$ | $x_{B_2}$ | $x_{H_2}$ | $x_{H_2O}$ | $x_{OH}$ | $x_{HF}$ | $x_{O_2}$ | $x_{F_2}$ | $x_H$ | $x_B$ | $x_F$ | $x_O$ | $x_A$ | $x_T$ | Const |
| **a** | 0 | 0 | 0 | 0 | 0 | 0 | 0.0058 | 0.0018 | 0.0150 | 0.3503 | 0 | 0 | 0.0867 | 0 | 0 | 0 | −0.4596 | 0 | 0.01238 |
| **b** | 0.1304 | 0.0156 | 0.0043 | 0 | 0.0053 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0019 | 0 | 0 | −1.1575 | 0 | 0.00235 |
| **c** | 0.3912 | 0 | 0.0043 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3503 | 0 | 0 | 0 | 0 | 0.0515 | 0 | −0.7973 | 0 | 0.00760 |
| **d** | 0 | 0.0234 | 0 | 0 | 0.0053 | 0 | 0 | 0.0009 | 0.0150 | 0 | 0.0538 | 0 | 0 | 0 | 0 | 0.2544 | −0.3528 | 0 | 0.02208 |
| **p** | 0.1304 | 0.0078 | 0.0043 | 0 | 0.0053 | 0 | 0.0029 | 0.0009 | 0.0150 | 0.3503 | 0.0269 | 0 | 0.0867 | 0.0019 | 0.0515 | 0.2544 | 0 | 0 | 0.02505 |
| **s** | 14.0848 | 0.9704 | 0.3559 | 0 | 0.4137 | 0 | 0.1751 | 0.0760 | 1.0552 | 21.4213 | 2.0438 | 0 | 3.7435 | 0.1140 | 2.8395 | 13.2827 | −62.4405 | 8.464 | 0.09447 |

(a) Submatrix $\left[\alpha_2 \mid \alpha_1\right]$.

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **a** | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **b** | 1 | 2 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **c** | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **d** | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| **q** | −62.075 | −80.593 | −17.288 | −8.300 | −18.183 | −7.989 | −13.939 | −29.209 | −13.603 | −19.674 | −15.313 | −8.705 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| **δ** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

(b) Submatrix $\left[\frac{-\alpha_1}{U_k}\right]$ transposed.

FIGURE 8.—Numerical example of submatrices of correction equations for isentropic expansion to 1 atmosphere for the reaction of diborane with oxygen bifluoride after first estimate of $n_i$, $A$, and $T$.

| | Gaseous molecules | | | | | | | | | | | | Atoms | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $x_{BF_3}$ | $x_{B_2O_3}$ | $x_{BF}$ | $x_{BH}$ | $x_{BO}$ | $x_{B_2}$ | $x_{H_2}$ | $x_{H_2O}$ | $x_{OH}$ | $x_{HF}$ | $x_{O_2}$ | $x_{F_2}$ | $x_H$ | $x_B$ | $x_F$ | $x_O$ | $x_A$ | $x_T$ | Const |
| a | 0 | 0 | 0 | 1.000 | 0 | 0 | 2.000 | 2.000 | 1.000 | 1.000 | 0 | 0 | 1.000 | 0 | 0 | 0 | −8.000 | 0 | −0.993 |
| b | 1.000 | 2.000 | 1.000 | 1.000 | 1.000 | 2.000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | −9.000 | 0 | −5.879 |
| c | 3.000 | 0 | 1.000 | 0 | 0 | 0 | 0 | 0 | 0 | 1.000 | 0 | 2.000 | 0 | 0 | 1.000 | 0 | −8.000 | 0 | 0.755 |
| d | 0 | 3.000 | 0 | 0 | 1.000 | 0 | 0 | 1.000 | 1.000 | 0 | 2.000 | 0 | 0 | 0 | 0 | 1.000 | −9.000 | 0 | −2.297 |
| s | 103.964 | 114.773 | 71.917 | 59.425 | 67.633 | 68.593 | 49.067 | 70.471 | 62.002 | 59.067 | 68.796 | 68.826 | 38.319 | 47.562 | 49.562 | 49.492 | −1030.944 | 161.162 | −163.234 |
| h* | 0.750 | 2.364 | 2.672 | 3.623 | 2.569 | 5.778 | 1.035 | 0.624 | 0.813 | 0.347 | 0.427 | 1.026 | 1.086 | 3.215 | 0.889 | 0.839 | −28.035 | −7.113 | −13.760 |

(a) Submatrix $\left[\alpha_1 \vdots \alpha_2\right]$.

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| b | 1 | 2 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| c | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| d | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| q | −62.075 | −80.593 | −17.288 | −8.300 | −18.183 | −7.969 | −13.939 | −29.209 | −13.603 | −19.674 | −15.313 | −8.705 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| δ | −5.695 | −5.109 | −1.634 | 2.611 | −1.033 | 2.768 | 0.406 | 0.347 | 0.167 | −1.894 | 0.380 | 3.137 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

(b) Submatrix $\left[\frac{-\alpha_1}{U_k}\right]$ transposed.

FIGURE 9.—Numerical example of submatrices of correction equations for isentropic expansion to local velocity of sound for reaction of diborane and oxygen bifluoride after first estimate of $n_i$, $A$ and $T$.

## TABLES OF THERMODYNAMIC PROPERTIES

Tables of thermodynamic data, completed June 1949, are presented for the following substances:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| A | Al(g) | B | C | Cl | F | H | $e^-$ | Li | N | O |
| | Al(s) | $B_2$ | CO | $Cl_2$ | $F_2$ | $H_2$ | $F^-$ | LiF | $N_2$ | $O_2$ |
| | Al(liq) | BF | $CO_2$ | ClF | | HCl | $Li^+$ | LiH | NO | OH |
| | AlO | $BF_3$ | | | | HF | | | | |
| | $Al_2O_3$(g) | BH | | | | $H_2O$ | | | | |
| | $Al_2O_3$(s) | BO | | | | | | | | |
| | $Al_2O_3$(liq) | $B_2O_3$(g) | | | | | | | | |
| | | $B_2O_3$(s) | | | | | | | | |
| | | $B_2O_3$(liq) | | | | | | | | |

These tables are taken from NACA TN 2161 except that the values for BF have been revised. Many of the data in the tables are based upon estimated vibrational frequencies or insufficient spectroscopic or thermochemical data to provide accurate data at high temperatures. Nevertheless, the data are considered sufficiently accurate for engineering evaluations of performance of aircraft propulsion systems until better data become available.

### PREPARATION OF TABLES

The values of enthalpy and entropy below 1000° K and the values of specific heat at all temperatures were based upon data taken from the literature or calculated by NACA from spectroscopic data or estimated fundamental frequencies. The calculations were made by use of the accurate summation method described in reference 8 or by the use of the tables prepared by F. J. Krieger of Douglas Aircraft Company, Inc. based upon a harmonic oscillator. The values of enthalpy and entropy above 1000° K were computed from the specific-heat data and these values were then used to compute the values of the remaining functions.

The thermodynamic functions computed by NACA are based upon the fundamental constants from reference 9 and are given in terms of the thermochemical calorie defined as 4.18400 absolute joules (reference 10).

**Specific heat.**—The specific-heat data were interpolated and extrapolated when necessary to obtain values of $C_p^\circ$ at 298.16° K and every 100° from 300° to 6000° K. In many cases these $C_p^\circ$ data were smoothed by the following method: Values of the first differences of $C_p^\circ$ for 100° K intervals $\delta C_p^\circ$ were plotted against temperature and a smooth curve drawn. New values of $C_p^\circ$ were then computed from the values of $\delta C_p^\circ$ read from the curve. In some cases the new $C_p^\circ$ values were tabulated to more decimal places than the original data. Care was taken to see that the new $C_p^\circ$ values were within about 1 or 2 units in the last tabulated place of the reference data in all but a few cases in which the reference data were irregular.

In order to minimize the labor required to integrate $C_p^\circ$ to obtain the other functions, a linear variation of $C_p^\circ$ was assumed by use of the equation

$$C_p^\circ = c_1 + c_2 T \tag{46}$$

where $c_1$ and $c_2$ are constants evaluated for each 100° temperature interval above 1000° K.

The maximum difference between a smooth function representing $C_p^\circ$ and the series of 50 straight-line segments represented by equation (46) is usually less than 0.005 percent at any temperature. In a few cases near 1000° K the error approaches 0.05 percent.

**Enthalpy and entropy.**—The data for enthalpy and entropy below 1000° K were taken from the literature or computed at the Lewis laboratory and when necessary interpolated to give the values at 298.16° K and every 100° from 300° to 1000° K.

The values above 1000° K were obtained by integration of equation (46) for $C_p^\circ$ using the constants for each 100° K temperature interval.

The value of the change of enthalpy $\delta H_T^\circ$ for a temperature change $\delta T = T - T_1$ is given by

$$\delta H_T^\circ = \int_{T_1}^{T} C_p^\circ dT = \overline{C}_p^\circ \delta T \tag{47}$$

where $\overline{C}_p^\circ$ is given by

$$\overline{C}_p^\circ = (C_p^\circ)_1 + \frac{c_2}{2}\,\delta T \tag{48}$$

and $(C_p^\circ)_1$ is the value of $C_p^\circ$ corresponding to the temperature $T_1$. The corresponding change in entropy $\delta S_T^\circ$ is given by

$$\delta S_T^\circ = \int_{T_1}^{T} \frac{C_p^\circ}{T}\, dT = c_1\, \delta \ln T + c_2\, \delta T \tag{49}$$

where $\delta \ln T$ is given by

$$\delta \ln T = \ln T - \ln T_1 \tag{50}$$

Values of enthalpy and entropy for each 100° above 1000° K were obtained by accumulatively adding to the values at 1000° K the changes of enthalpy and entropy computed for each 100° interval by means of equations (47) and (49).

The values of enthalpy and entropy were computed to more decimal places than are tabulated and then rounded. Equations (47) and (49) may therefore occasionally yield values that differ by one unit in the last tabulated place of enthalpy and entropy because of rounding. Inconsistencies from this source are unavoidable and are not considered in the following discussion.

The representation of $C_p^\circ$ from 1000° to 6000° K by means of 50 straight-line segments permitted computation of self-consistent values of enthalpy and entropy but lead to values slightly different from those that would have resulted from a more laborious integration of a smooth $C_p^\circ$ function. For example, the values of enthalpy at 6000° K differ from those obtained by applying Simpson's one-third rule by 0.0045, 0.0012, 0.0038, and 0.0031 percent for $H_2O$, $H_2$, $CO_2$, and $BF_3$, respectively.

In a few cases, discrepancies exist between the reference values of enthalpy and the values of enthalpy given herein that cannot be accounted for by the error resulting from the method of integration used. From an analysis of the values in the reference tables, these discrepancies appear to be caused by a combination of small inconsistencies and rounding errors in the references. The maximum discrepancy noted in enthalpy occurred in $H_2O$ and was less than 0.25 percent of the value of $H_T^\circ - H_0^\circ$.

**Enthalpy $H_T^\circ$.**—For convenience of computation, tables of enthalpy $H_T^\circ$, the sum of the sensible enthalpy $H_T^\circ - H_0^\circ$ and chemical energy at 0° K $H_0^\circ$, were prepared. An arbitrary base may be adopted for assigning absolute values to the enthalpy of various substances inasmuch as only differences in enthalpy are measurable. The base used in these tables was selected to obtain positive values for $H_T^\circ$ of the substances commonly used as rocket and ram-jet propellants and occurring in the products of combustion; it is shown in the following table:

| Base substance | Phase | Temperature (°K) | Enthalpy assigned, $H_T^\circ$ (kcal/mole) |
|---|---|---|---|
| A | Gas | 0 | 0 |
| $AlF_3$ | Crystal | 298.16 | 0 |
| $BF_3$ | Gas | 0 | 0 |
| $CO_2$ | Gas | 0 | 0 |
| $Cl_2$ | Gas | 298.16 | 10 |
| HF | Gas | 0 | 0 |
| $H_2O$ | Crystal | 0 | 0 |
| LiF | Gas | 298.16 | 80 |
| $N_2$ | Crystal | 0 | 0 |
| $O_2$ | Crystal | 0 | 0 |
| $e-$ | Gas | 0 | 60 |

In determining the value of $H_T^\circ$ to be assigned to a substance having a known heat of formation, it is convenient to use the values of $H_T^\circ$ assigned to the elements as shown in the following table:

| Element | Phase | Enthalpy assigned, $H_T^\circ$ (kcal/mole) | |
|---|---|---|---|
| | | 0° K | 298.16° K |
| A | Gas | 0 | 1.4812 |
| Al | Crystal | 233.6251 | 234.0951 |
| B | Crystal | -------- | 173.3793 |
| C | Graphite | 91.9274 | 92.1790 |
| $Cl_2$ | Gas | 7.8061 | 10.0000 |
| $F_2$ | Gas | 60.9562 | 63.0699 |
| $H_2$ | Gas | 67.4169 | 69.4407 |
| Li | Crystal | -------- | 132.2250 |
| $N_2$ | Gas | 1.6992 | 3.7715 |
| $O_2$ | Gas | 2.0362 | 4.1109 |
| $e-$ | Gas | 60.0000 | 61.4812 |

For example, if the value of enthalpy $H_T^\circ$ to be assigned to $H_2O$ (liq) is to be determined at 298.16° K, the reaction of formation would be

$$H_2 + \frac{1}{2} O_2 \rightarrow H_2O \tag{51}$$

and $\Delta H_f^\circ$ is defined as

$$\Delta H_f^\circ = (H_T^\circ)_{H_2O} - (H_T^\circ)_{H_2} - \frac{1}{2}(H_T^\circ)_{O_2} \tag{52}$$

therefore,

$$(H_T^\circ)_{H_2O} = \Delta H_f^\circ + (H_T^\circ)_{H_2} + \frac{1}{2}(H_T^\circ)_{O_2} \tag{53}$$

With the use of the value $\Delta H_f^\circ = -68.3174$ (kcal/mole),

$$(H_{298.16}^\circ)_{H_2O(liq)} = -68{,}317.4 + 69{,}440.7 + \frac{1}{2}(4110.9)$$

$$= 3178.75 \text{ (cal/mole)}$$

For convenience, the values of $H_T^\circ$ thus assigned to a number of compounds have been computed with the aid of data from references 8 and 10 to 23 and are listed in table II. The energy of gas imperfections has been included in computing the values of $H_T^\circ$ assigned to the liquid phase of ammonia, $n$-butane, chlorine, hydrogen, and water.

$-\Delta H^\circ/RT$ and $\ln K$.—From the values of $H_T^\circ$ and $S_T^\circ$ obtained as previously described, the values of $-\Delta H^\circ/RT$ and $\ln K$ were computed for the reaction of formation of each substance from its elements in the atomic gas state. For example, the reaction of formation of $H_2O$ is

$$2H+O\rightarrow H_2O \tag{54}$$

From the definitions of $\Delta H^\circ$ and $\ln K$

$$\frac{\Delta H^\circ}{RT}=\frac{(H_T^\circ)_{H_2O}-2(H_T^\circ)_H-(H_T^\circ)_O}{RT} \tag{55}$$

and

$$\ln K=\frac{(S_T^\circ)_{H_2O}-2(S_T^\circ)_H-(S_T^\circ)_O}{R}-\frac{(H_T^\circ)_{H_2O}-2(H_T^\circ)_H-(H_T^\circ)_O}{RT} \tag{56}$$

As shown by equations (3) and (4), $K$ may be expressed in terms of partial pressures. For example, for gaseous $H_2O$,

$$K=\frac{p_{H_2O}}{p_H{}^2p_O}$$

The values of $\ln K$ have been converted to $\log K$ in the tables for convenience.

## INTERPOLATION OF TABLES

Interpolation formulas are given that permit computation of self-consistent values of the thermodynamic functions at temperatures intermediate to those tabulated. Linear interpolation is recommended for simplicity, however, when a high degree of self-consistency is not required. Interpolation formulas such as those of Newton or Lagrange will give values near the self-consistent value. Inasmuch as the tables are based on linear variations in $C_p^\circ$, linear interpolation yields self-consistent results for the $C_p^\circ$ function. An example of the values obtained by the interpolation formulas given and by linear interpolation is shown for each function.

**Interpolation of specific heat.**—The value of $C_p^\circ$ for any temperature $T$ is given by

$$C_p^\circ=(C_p^\circ)_1+\frac{\delta T}{T_2-T_1}[(C_p^\circ)_2-(C_p^\circ)_1] \tag{57}$$

where $(C_p^\circ)_1$ and $(C_p^\circ)_2$ are the tabular values corresponding to the tabular temperatures $T_1$ and $T_2$ between which $T$ lies and $\delta T=T-T_1$. For example, the value of $C_p^\circ$ for $H_2O$ at 1573.4° K is computed to be

$$C_p^\circ=11.134+\frac{73.4}{100}(11.343-11.134)$$

$$=11.287\ (\text{cal/(mole) (°K)})$$

**Interpolation of enthalpy.**—The value of $H_T^\circ$ for any temperature $T$ is given by

$$H_T^\circ=(H_T^\circ)_1+\overline{C}_p^\circ\delta T \tag{58}$$

where $(H_T^\circ)_1$ is the value listed at $T_1$ and where

$$\overline{C}_p^\circ=\frac{(C_p^\circ)_1+C_p^\circ}{2}$$

For example, for $H_2O$ at 1573.4° K

$$\overline{C}_p^\circ=\frac{11.134+11.287}{2}=11.211\ (\text{cal/(mole) (°K)})$$

$$H_T^\circ=25{,}202.3+11.211\times 73.4=26{,}025.2\ (\text{cal/mole})$$

By linear interpolation,

$$H_T^\circ=26{,}027.2\ (\text{cal/mole})$$

**Interpolation of entropy.**—Self-consistent values of entropy may be obtained with the aid of equation (49), which may approximated by

$$\delta S_T^\circ=\overline{C}_p^\circ\ \delta\ln T \tag{60}$$

from which $S_T^\circ$ may be written

$$S_T^\circ=(S_T^\circ)_1+\overline{C}_p^\circ\ \delta\ln T \tag{61}$$

where $(S_T^\circ)_1$ is the value listed at $T_1$.

Equation (61) yields self-consistent values to within 0.0001 (cal/(mole) (°K)) for all substances tabulated at temperatures above 1600° K and for all substances except $Al_2O_3$ (s and g), $BF_3$, $B_2O_3$ (liq and g), $CO_2$, and $H_2O$ for temperatures from 1000° to 1600° K. For these substances, the error due to use of equation (61) does not exceed 0.0003 cal/(mole) (°K)), but equation (49) may be used if greater self-consistency is desired.

For example, for $H_2O$ at 1573.4° K,

$$S_T^\circ=59.8687+11.211\ (\ln\ 1573.4-\ln\ 1500)$$

$$=60.4043\ (\text{cal/(mole) (°K)})$$

By linear interpolation,

$$S_T^\circ=60.4010\ (\text{cal/(mole) (°K)})$$

**Interpolation of $-\Delta H^\circ/RT$ and $\log K$.**—The values of $-\Delta H^\circ/RT$ and $\log K$ for any temperature $T$ are given by

$$\frac{-\Delta H^\circ}{RT}=\left(\frac{-\Delta H^\circ}{RT}\right)_1-\frac{\delta T}{100}\left(\frac{a}{T}+b\right) \tag{62}$$

and

$$\log K=(\log K)_1-\frac{\delta T}{100}\left(\frac{c}{T}+d\right) \tag{63}$$

where $(-\Delta H^\circ/RT)_1$ and $(\log K)_1$ are the values corresponding to $T_1$ and where $a$, $b$, $c$, and $d$ are interpolation coefficients corresponding to $T_1$.

For example, for $H_2O$ at 1573.4° K,

$$\frac{-\Delta H^\circ}{RT}=76.3615-\frac{73.4}{100}\left(\frac{7366}{1573.4}+0.05315\right)=72.8862$$

By linear interpolation,

$$\frac{-\Delta H^\circ}{RT}=72.9433$$

and for $\log K$,

$$\log K=20.5727-\frac{73.4}{100}\left(\frac{3276}{1573.4}+0.02690\right)=19.0247$$

By linear interpolation,

$$\log K=19.0501$$

## SOURCES OF DATA

A summary of the heat of formation and spectroscopic constants used in computing the tables and the references from which these data were taken are given in table III together with a summary of the source and the treatment of specific-heat, enthalpy, and entropy data. Additional discussion for a few substances follows.

**$Al_2O_3$(s, liq, g).**—The properties of $Al_2O_3$ in the solid, liquid, and gaseous phases were approximated by starting with data at 298.16° K for the solid phase and computing the properties of each phase from specific-heat data and enthalpy changes associated with phase changes. The specific heat for the solid was computed from a formula for $C_p^\circ$ given in reference 27. The value of $S^\circ_{298.16}$ for the solid was taken from selected values of National Bureau of Standards (issued undated but prior to June 30, 1948). The values of enthalpy and entropy up to 1000° K were then found by integration of the $C_p^\circ$ formula given in reference 27. The heat of fusion ($\Delta H^\circ_{fusion}$=6000 cal/mole at 2320° K) was taken from reference 25. The $C_p^\circ$ values for $Al_2O_3$ (liq) above 2320° K were calculated from a formula based upon data given in reference 25.

Inasmuch as data on gaseous $Al_2O_3$ are unavailable in the literature, it was assumed that $C_p^\circ$ values for $Al_2O_3$(g) are the same as those for $B_2O_3$(g) given in reference 29. The heat of vaporization ($\Delta H^\circ_{vaporization}$=115.7 kcal/mole at boiling point of 2980±60° C) was taken from reference 40. The uncertainty in the values given for entropy and enthalpy is estimated to be ±10 percent.

**BF.**—Since publication of Technical Note 2161, new thermodynamic data have been computed for BF based upon a $^1\Sigma$ ground state and a dissociation energy of 4.3 electron volts as quoted by reference 30.

**$BF_3$.**—The thermodynamic functions of $BF_3$ were computed by the rigid-rotator–harmonic-oscillator approximation with the following spectroscopic data given in references 31 and 41:

| Vibrational frequencies | | | Moment of inertia |
|---|---|---|---|
| | $B^{11}F_3$ (cm$^{-1}$) | $B^{10}F_3$ (cm$^{-1}$) | (g) (cm$^2$) |
| $\nu_1$ | 888 | 888 | $I_1$=157.7×10$^{-40}$ |
| $\nu_2$ | 691.3 | 719.5 | $I_2$=78.84×10$^{-40}$ |
| $\nu_3$(2) | 1445.9 | 1497 | $I_3$=78.84×10$^{-40}$ |
| $\nu_4$(2) | 480.4 | 482.0 | |
| Relative abundance (percent) | 81.17 | 18.83 | |

**$B_2O_3$ (g).**—The value for the heat required to convert solid $B_2O_3$ at 0° K to gaseous $B_2O_3$ at 1500° K listed in reference 29 as 106.065 (kcal/mole) was used to compute the value of $(H^\circ_{1500})_{B_2O_3(g)}$. The values of $(S^\circ_{1500})_{B_2O_3(g)}$ and $(H^\circ_{1500}-H^\circ_0)_{B_2O_3(g)}$ were taken from reference 29. The remaining values of enthalpy and entropy were computed by integration of the specific-heat data.

**$Cl_2$ and HCl.**—The $C_p^\circ$ data for $Cl_2$ and HCl from 1000° to 6000° K were taken from unpublished data obtained at the Jet Propulsion Laboratory of the California Institute of Technology.

**ClF, F, and $F^-$.**—Recent spectroscopic and thermochemical measurements on compounds of fluorine (reference 42) have indicated that the values of the heat of formation of ClF, F, and $F^-$ are considerably less than the values given in reference 18. In a communication in May 1949, Dr. F. D. Rossini of the National Bureau of Standards listed their best current estimate for the heat of formation of ClF and F as −13.2 and 17.8 (kcal/mole), respectively. In accordance with these new values, the value of the heat of formation of $F^-$ has been recalculated from data in reference 18.

**HF.**—The values of $C_p^\circ$, $H_T^\circ-H_0^\circ$, and $S_T^\circ$ for HF at 298.16° K 600° K, and every 1000° from 1000° to 6000° K were computed from spectroscopic data given in reference 36 using the accurate summation process. Intermediate values of $C_p^\circ$ were interpolated. Subsequent to the completion of computations for this substance, new spectroscopic data were made available by Dr. A. H. Nielsen of the University of Tennessee. Values of $C_p^\circ$, $H_T^\circ-H_0^\circ$, and $S_T^\circ$ at 5000° K computed with these data differ from values herein by 1 percent for $C_p^\circ$, 0.2 percent for $H_T^\circ-H_0^\circ$, and 0.03 percent for $S_T^\circ$.

**$e^-$, $F^-$, and $Li^+$.**—The use of metals with low ionization potentials introduces the possibility of the formation of appreciable quantities of ionized products. Because the partial pressure of ions is expected to be small, the zero-pressure properties of electron gas $e^-$ have been tabulated from reference 38. The properties of $F^-$ have been computed on the assumption that only the ground electronic state is stable. (See reference 43, p. 218.) The contributions of all energy levels above the ground level to the thermodynamic functions of $Li^+$ are negligible. The value of $C_p^\circ$ tabulated for all these substances is $\frac{5}{2}R$.

**Li.**—In computing the thermodynamic functions of Li, the summation was carried over the first five energy levels.

**LiF.**—Spectroscopic data for LiF gas were not found in the literature. A vibrational frequency for the ground state of 1343 (cm$^{-1}$) and a moment of inertia $I_e$=15.415×10$^{-40}$ (gm) (cm$^2$) were graphically estimated from a plot of force constants against difference in atomic number of the two elements composing the substances NaH, $C_2$, and BeO, each substance of which is isoelectronic with LiF. It is expected that the anharmonicity constant for LiF is sufficiently large to increase materially the computed value of the specific heat. The uncertainty in the value of the enthalpy and the entropy is estimated to be ±10 percent at 5000° K.

**LiH.**—Spectroscopic data for $Li^7H^1$ given in reference 26 were modified for the normal isotopic mixture LiH using relative abundance percentages of isotopes and atomic weights given in reference 44 (pp. 163 and 188, respectively). The value obtained for the vibrational frequency of the ground state of LiH is 1360.37 (cm$^{-1}$) and for the moment of inertia is 3.77246×10$^{-40}$ (gm) (cm$^2$).

**$H_2O$(s), $N_2$(s), and $O_2$(s).**—The heat required to heat solid $H_2O$, $N_2$, and $O_2$ from 0° to 298.16° K in the natural state was taken from reference 37.

**New data.**—Subsequent to the completion of the computation for $H_2$, new values for $C_p^\circ$, internal energy $E^\circ-E_0^\circ$, and $S_T^\circ$ were published in reference 45 and differ from the values in this report at 5000° K by 0.5 percent for $C_p^\circ$, 0.1 percent for $H_T^\circ-H_0^\circ$, and 0.02 percent for $S_T^\circ$.

### TABLES OF THERMODYNAMIC PROPERTIES

The values of the functions of the 42 substances are given in tables IV to XLV at 298.16° K and every 100° from 300° to 6000° K together with interpolation coefficients for $-\Delta H^\circ/RT$ and log $K$ at every 100° from 1000° to 6000° K.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
CLEVELAND, OHIO, *January 26, 1950*.

## APPENDIX—SYMBOLS

The following symbols are used in this report:

| | |
|---|---|
| $A$ | number of formula weights of reactants |
| $a,b,\ldots$ | summation of each atomic type over products of reaction per equivalent formula; with subscript, number of atoms of each element within chemical formula; in thermodynamic tables, interpolation coefficients |
| $C_p^\circ$ | molar specific heat at constant pressure and standard conditions (cal/(mole) (°K)) |
| $C',C''$ | specific heat coefficient for matrix |
| $C_v^\circ$ | molar specific heat at constant volume and standard conditions |
| $D$ | operator $\left(\frac{\partial \log}{\partial \log T}\right)_s$ |
| $E_T^\circ$ | molar internal energy at standard conditions |
| $\epsilon$ | internal energy per equivalent formula |
| $F_T^\circ$ | molar free energy at standard conditions |
| g | gas phase of substance |
| $H_0^\circ$ | chemical energy at 0° K and standard conditions (kcal/mole) |
| $H_T^\circ$ | sum of sensible enthalpy and chemical energy at temperature $T$ and standard conditions (kcal/mole) |
| $H_T^\circ - H_0^\circ$ | sensible enthalpy at temperature $T$ and standard conditions (kcal/mole) |
| $\frac{\Delta H^\circ}{RT}$ | enthalpy change due to formation of substance from its elements in atomic gas state divided by $RT$ |
| $\Delta H_f^\circ$ | enthalpy change due to formation of substance from its elements in standard state (kcal/mole) |
| $h$ | enthalpy per equivalent formula |
| $h',h''$ | enthalpy coefficient for matrix |
| $h^*$ | sum of heat and kinetic energies per equivalent formula |
| $hc/k$ | ratio of Planck's constant times velocity of light to Boltzmann's constant, 1.43847 (cm) (°K) |
| $I$ | moment of inertia (gm) (cm²) |
| $J$ | dimensional constant |
| $K$ | equilibrium constant |
| liq | liquid phase of substance |
| $M$ | Mach number |
| $M_r$ | molecular weight of equivalent formula |
| $m$ | mass flow per second |
| $N$ | number of products of reaction |
| $n$ | number of moles |
| $P$ | total pressure |
| $p$ | partial pressure |
| $Q$ | any function |
| $q,r$ | any variables; with subscript, matrix symbol for $\frac{\Delta H}{RT}$ |
| $R$ | universal gas constant, 1.98718 (cal/(mole) (°K)) |
| $S_T^\circ$ | molar entropy at standard conditions (cal/(mole) (°K)) |
| $s$ | entropy per equivalent formula; in thermodynamic tables, solid phase of substance |
| $s'$ | entropy coefficient for matrix |
| $T$ | temperature (°K) |
| $t$ | throat area |
| $U_m, U_k$ | unit matrix |
| $u$ | velocity of sound |
| $V$ | volume |
| $v$ | velocity of flow |
| $Z,Y,\ldots$ | elements within representative chemical formula |
| $x$ | correction variables |
| $\alpha_1,\alpha_2,\ldots$ | submatrices |
| $\Delta$ | increment |
| $\delta$ | increment due to a temperature change; with subscript, error parameter |
| $\epsilon$ | total-error parameter |
| $\nu_1,\nu_2,\nu_3(2)$ $\nu_4(2)$ | spectroscopic constants |
| $\omega_e,\omega_e x_e$ | spectroscopic constants |
| $\rho$ | density |
| Subscripts: | |
| $a,b,\ldots$ | number of atoms within chemical formula |
| $f$ | fuel |
| $g$ | oxidant |
| $l$ | any point in nozzle |
| $m$ | number of types of gaseous molecule |
| $o$ | initial given condition |
| $P$ | constant pressure |
| $s$ | constant entropy |
| $T$ | temperature (°K) |
| $\ldots Y,Z$ | product index numbers ($i$) that designate atomic gases |
| $1,2,\ldots,i,\ldots N$ | product index number |

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TABLE I—VALUES OF CONSTANTS FOR REACTION OF DIBORANE WITH OXYGEN BIFLUORIDE ($B_2H_6+5F_2O$)

| Product | Fixed | | | | | Determined at estimated temperature of 4000° K | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $i$ | $b_i$ | $a_i$ | $c_i$ | $d_i$ | $(H_T^\circ)_i$ kcal/mole | $(\Delta H_T^\circ/RT)_i$ | $(S_T^\circ)_i$ | $(C_p^\circ)_i$ | log $K_i$ |
| Equivalent formula | 0 | 2 | 6 | 10 | 5 | | | | | |
| $BF_3$ | 1 | 1 | 0 | 3 | 0 | 72.172 | −62.0753 | 105.951 | 19.738 | 5.6953 |
| $B_2O_3$ | 2 | 2 | 0 | 0 | 3 | 233.435 | −80.5932 | 116.760 | 25.660 | 5.1094 |
| BF | 3 | 1 | 0 | 1 | 0 | 262.961 | −17.2884 | 73.904 | 8.905 | 1.6342 |
| BH | 4 | 1 | 1 | 0 | 0 | 356.994 | −8.3004 | 61.412 | 8.826 | −2.6110 |
| BO | 5 | 1 | 0 | 0 | 1 | 252.739 | −18.1834 | 69.620 | 9.065 | 1.0327 |
| $B_2$ | 6 | 2 | 0 | 0 | 0 | 572.053 | −7.9892 | 70.580 | 8.923 | −2.7625 |
| $H_2$ | 7 | 0 | 2 | 0 | 0 | 99.593 | −13.9385 | 51.054 | 9.151 | −0.4061 |
| $H_2O$ | 8 | 0 | 2 | 0 | 1 | 57.706 | −29.2092 | 72.458 | 13.300 | −0.3470 |
| OH | 9 | 0 | 1 | 0 | 1 | 76.560 | −13.6031 | 63.989 | 9.165 | −0.1668 |
| HF | 10 | 0 | 1 | 1 | 0 | 32.016 | −19.6736 | 61.054 | 9.045 | 1.8944 |
| $O_2$ | 11 | 0 | 0 | 0 | 2 | 37.310 | −15.3125 | 70.753 | 9.932 | −0.3804 |
| $F_2$ | 12 | 0 | 0 | 2 | 0 | 96.012 | −8.7047 | 70.813 | 9.451 | −3.1373 |
| H | 13 | 0 | 1 | 0 | 0 | 105.192 | ------------- | 40.306 | 4.968 | ------------- |
| B | 14 | 1 | 0 | 0 | 0 | 317.778 | ------------- | 49.549 | 4.968 | ------------- |
| F | 15 | 0 | 0 | 1 | 0 | 82.601 | ------------- | 51.230 | 4.974 | ------------- |
| O | 16 | 0 | 0 | 0 | 1 | 79.493 | ------------- | 51.479 | 5.091 | ------------- |

TABLE II—ENTHALPY $H_T^\circ$ ASSIGNED TO SEVERAL SUBSTANCES

| Substance | Formula | Phase | Temperature (°K) | Heat of formation, $\Delta H_f$ (kcal/mole) | Enthalpy assigned, $H_T^\circ$ (kcal/mole) | Reference |
|---|---|---|---|---|---|---|
| Acetylene | $C_2H_2$ | Gas | 298.16 | 54.194 | 307.993 | 11 |
| | | Liquid [a] | 191.7 | ------------- | 302.75 | 12 |
| Air [b] | ----- --------- | Gas | 298.16 | 0 | 3.8208 | 13 |
| Aluminum | Al | Crystal | 298.16 | 0 | 234.6951 | 10 |
| Ammonia | $NH_3$ | Gas | 298.16 | −11.04 | 95.01 | ---------- |
| | | Liquid | 239.76 | ------------- | [c]88.91 | 10, 14 |
| Aniline | $C_6H_5NH_2$ | Liquid | 298.16 | [d]8.18 | 806.19 | 14 |
| n-Butane | $C_4H_{10}$ | Gas | 298.16 | −29.812 | 686.108 | 12 |
| | | Liquid | 272.66 | ------------- | [c]680.126 | 12, 14 |
| Chlorine | $Cl_2$ | Gas | 298.16 | 0 | 10.000 | ---------- |
| | | Liquid | 239.11 | ------------- | [c]4.61 | 15 |
| Chlorine trifloride | $ClF_3$ | Liquid | 298.16 | [e]−32.1 | 67.5 | ---------- |
| Diborane | $B_2H_6$ | Gas | 298.16 | 7.5 | 562.6 | 16 |
| | | Liquid | 180.63 | ------------- | 557.8 | 16, 17 |
| Ethylene-diamine | $C_2H_8N_2$ | Liquid | 298.16 | −6.30 | 459.53 | 11 |
| Fluorine | $F_2$ | Gas | 298.16 | 0 | 63.0699 | ---------- |
| | | Liquid | 85.24 | ------------- | 60.04 | 18 |
| Fluorine oxide | $F_2O$ | Gas | 298.16 | 5.5 | 70.6 | 18 |
| | | Liquid | 128.3 | ------------- | 66.4 | 18 |
| Gasoline [f] | AN-F-58 | Liquid | 298.16 | −47.50 | 1346.60 | ---------- |
| Heptane | $C_7H_{16}$ | Liquid | 298.16 | −53.63 | 1147.15 | 12 |
| Hexane | $C_6H_{14}$ | Liquid | 298.16 | −47.52 | 991.64 | 12 |
| Hydrazine | $N_2H_4$ | Liquid | 298.16 | 12.05 | 154.70 | 10 |
| Hydrazine hydrate | $N_2H_4.H_2O$ | Liquid | 298.16 | −57.95 | 156.20 | 10 |
| Hydrogen | $H_2$ | Gas | 298.16 | 0 | 69.4407 | ---------- |
| | | Liquid | 20.39 | ------------- | [c]67.540 | 19 |
| Hydrogen peroxide | $H_2O_2$ | Liquid | 298.16 | −44.84 | 28.71 | 18 |
| Hydroxylamine | $NH_2OH$ | Liquid | 298.16 | −25.5 | 82.6 | 10 |
| Lithium | Li | Crystal | 298.16 | 0 | 132.2250 | ---------- |
| | | Liquid | 459.16 | ------------- | 134.53 | 20, 21 |
| Lithium borohydride | $LiBH_4$ | Crystal | 298.16 | −44.15 | 400.34 | 22 |
| Methane | $CH_4$ | Gas | 298.16 | −17.889 | 213.171 | 12 |
| | | Liquid | 111.67 | ------------- | 209.71 | 12 |
| Methanol | $CH_3OH$ | Liquid | 298.16 | −57.036 | 176.080 | 23 |
| Nitric acid, white fuming | $HNO_3$ | Liquid | 298.16 | −41.404 | 1.368 | 10 |
| Nitrogen tetraoxide | $N_2O_4$ | Gas | 298.16 | 2.309 | 14.302 | 10 |
| | | Liquid | 294.31 | ------------- | 5.120 | 10 |
| Nitrogen trifloride | $NF_3$ | Gas | 298.16 | −27.2 | 69.3 | 10 |
| | | Liquid | 144.1 | ------------- | 64.6 | 10 |
| Nitromethane | $CH_3NO_2$ | Liquid | 298.16 | −26.7 | 175.6 | 23 |
| n-Octane | $C_8H_{18}$ | Liquid | 298.16 | −59.74 | 1302.66 | 12 |
| Oxygen | $O_2$ | Gas | 298.16 | 0 | 4.1109 | ---------- |
| | | Liquid | 90.16 | ------------- | 1.0314 | 8, 18 |
| Ozone | $O_3$ | Gas | 298.16 | 34.0 | 40.2 | 18 |
| | | Liquid | 162.65 | ------------- | 36.4 | 18 |
| Pentaborane | $B_5H_9$ | Liquid | 298.16 | 7.8 | 1187.2 | 16 |
| Tetranitromethane | $C(NO_2)_4$ | Liquid | 298.16 | 5 | 121 | 23 |
| Water | $H_2O$ | Gas | 298.16 | −57.7979 | 13.6988 | 18 |
| | | Liquid | 298.16 | ------------- | [c]3.1788 | 18 |

[a] For pressure of 900 mm Hg.
[b] For composition consisting of following mole fractions: $N_2$, 0.780881; $O_2$, 0.209495; A, 0.009324; $CO_2$, 0.000300.
[c] Energy of gas imperfections included.
[d] Computed from heat of combustion.
[e] Estimate based upon unpublished value of −26.4 kcal/mole at 200° C obtained by Dr. Swinehart of Harshaw Chemical Compan
[f] Based upon representative sample having molecular weight of 122 and hydrogen-carbon atom ratio of 1.942.

## TABLE III—THERMOCHEMICAL AND SPECTROSCOPIC DATA AND REFERENCES FOR EACH SUBSTANCE

| Substance | Phase | Heat of formation, $\Delta H_f^\circ$ (kcal/mole) | | Spectroscopic constants | | Reference | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0° K | 298.16° K | $\omega_e - 2\omega_e x_e$ (cm$^{-1}$) | Moment of inertia (gm)(cm$^2$) $\times 10^{-40}$ | Heat of formation | Spectroscopic constants | Specific heat, enthalpy, and entropy (0° to 1000° K) | Specific heat (1000° to 6000° K) |
| A | Gas | 0 | 0 | | | | 24 | (a) | (a) |
| Al | Gas | | 67.50 | | | (b) | 24 | (a) | (a) |
| Al | Crystal | 0 | 0 | | | | | 25 | |
| Al | Liquid | | | | | | | 25 | [c,d] 25 |
| $AlF_3$ | Crystal | | −329.3 | | | (b) | | | |
| AlO | Gas | | 87.8 | 963 | 43.8223 | (b) | 26 | (e) | (e) |
| $Al_2O_3$ | Gas | | | | | | | | (f) |
| $Al_2O_3$ | Crystal, α | | −399.09 | | | (b) | | [f] 27 | 27 |
| $Al_2O_3$ | Liquid | | | | | | | | [f] 25 |
| B | Gas | | 97.2 | | | 28 | 29 | (a) | (a) |
| B | Crystal | 0 | 0 | | | | | | |
| $B_2$ | Gas | | 124 | | | 28 | | [g] 29 | [c,d,g] 29 |
| BF | Gas | | −16.9308 | 1304.84 | 19.9465 | [h] 30 | [f] 30 | (e) | (e) |
| $BF_3$ | Gas | | −265.2 | | | 28 | [f] 31 | (e) | (e) |
| BH | Gas | | 73.8 | 2268 | 2.36939 | 28 | 26 | (e) | (e) |
| BO | Gas | | −5.2 | | | 28 | | [g] 29 | [c,d,g] 29 |
| $B_2O_3$ | Gas | | | | | (f) | | | [c,d,g] 29 |
| $B_2O_3$ | Crystal | | −302.0 | | | 28 | | 29 | |
| $B_2O_3$ | Liquid | | | | | | | [c] 29 | [c,d,g] 29 |
| C | Gas | | 171.698 | | | 23 | | 11 | [c,d,g] 11 |
| C | Graphite | 0 | 0 | | | | | | |
| CO | Gas | | −26.4157 | | | 23 | | 32 | [c,d,g] 11 |
| $CO_2$ | Gas | | −94.0518 | | | 23 | | 32 | [c,d,g] 11 |
| Cl | Gas | 28.61 | | | | 33 | | 11 | [c,d,g] 11 |
| $Cl_2$ | Gas | 0 | | | | | | 11 | (f) |
| ClF | Gas | | −13.2 | 778 | 54.35 | (f) | 34 | (e) | (e) |
| F | Gas | 17.8 | | | | (f) | 35 | (a) | (a) |
| $F_2$ | Gas | 0 | 0 | 856 | 33.3564 | | 36 | (e) | (e) |
| H | Gas | 51.620 | | | | 18 | | 32 | 32 |
| $H_2$ | Gas | 0 | 0 | | | | | 32 | [c,d,g] 19 |
| HCl | Gas | | −22.063 | | | 11 | | 11 | (f) |
| HF | Gas | | −64.2 | | | 18 | 36 | (f) | (f) |
| $H_2O$ | Gas | | −57.7974 | | | 18 | | 11 | [c,d,g] 11 |
| $H_2O$ | Crystal | −68.4350 | | | | [h] 37 | | | |
| $H_2O$ | Liquid | | −68.3174 | | | 18 | | | |
| $e^-$ | Gas | 0 | 0 | | | | | [f] 38 | 38 |
| $F^-$ | Gas | −78.5 | | | | [h] 18 | (f) | (a) | (a) |
| $Li^+$ | Gas | | 161.4664 | | | [h] 24 | 24 | (a) | (a) |
| Li | Gas | | 36.150 | | | [i] 20 | 24 | (a) | (a) |
| Li | Crystal | 0 | 0 | | | | | | |
| LiF | Gas | | −83.766 | 1343 | 15.415 | [i] 20 | (f) | (e) | (e) |
| LiH | Gas | | 25.4564 | 1360.37 | 3.77246 | [h,i] 39 | [f] 26 | (e) | (e) |
| N | Gas | 85.120 | | | | 10 | | 32 | [c,d,g] 11 |
| $N_2$ | Gas | 0 | 0 | | | | | 32 | [c,d,g] 11 |
| $N_2$ | Crystal | −1.6992 | | | | [h] 37 | | | |
| NO | Gas | 21.477 | | | | 10 | | 18 | [c,d,g] 11 |
| O | Gas | 58.586 | | | | 32 | | 32 | [c,d,g] 11 |
| $O_2$ | Gas | 0 | 0 | | | | | 8 | [c,d,g] 8 |
| $O_2$ | Crystal | −2.0362 | | | | [h] 37 | | | |
| OH | Gas | 10.0 | | | | 18 | | 32 | [c,d,g] 11 |

[a] Specific heat, enthalpy, and entropy at 298.16° and every 100° from 300° to 1000° and specific heat for each 100° from 1000° to 6000° K were computed from spectroscopic data given in reference listed by accurate summation method.
[b] Data from selected values of National Bureau of Standards issued undated but prior to June 30, 1948.
[c] Graphically smoothed.
[d] Extrapolated.
[e] Specific heat, enthalpy, and entropy at 298.16° and every 100° from 300° to 1000° and specific heat for each 100° from 1000° to 6000° K were computed from spectroscopic data by rigid rotator-harmonic oscillator approximation.
[f] See discussion in text.
[g] Interpolated.
[h] Computed with aid of data in reference listed.
[i] Unpublished data from Battelle Memorial Institute also used.

## TABLE IV—THERMODYNAMIC PROPERTIES OF A (ARGON GAS)

[Atomic weight, 39.944]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ |
|---|---|---|---|---|
| 0 | ---------- | 0 | 0 | ---------- |
| 298.16 | 4.9680 | 1.4812 | 1.4812 | 36.9830 |
| 300 | 4.9680 | 1.4904 | 1.4904 | 37.0135 |
| 400 | 4.9680 | 1.9872 | 1.9872 | 38.4427 |
| 500 | 4.9680 | 2.4840 | 2.4840 | 39.5513 |
| 600 | 4.9680 | 2.9808 | 2.9808 | 40.4570 |
| 700 | 4.9680 | 3.4776 | 3.4776 | 41.2229 |
| 800 | 4.9680 | 3.9744 | 3.9744 | 41.8862 |
| 900 | 4.9680 | 4.4712 | 4.4712 | 42.4714 |
| 1,000 | 4.9680 | 4.9680 | 4.9680 | 42.9948 |
| 1,100 | 4.9680 | 5.4648 | 5.4648 | 43.4683 |
| 1,200 | 4.9680 | 5.9616 | 5.9616 | 43.9006 |
| 1,300 | 4.9680 | 6.4584 | 6.4584 | 44.2982 |
| 1,400 | 4.9680 | 6.9552 | 6.9552 | 44.6664 |
| 1,500 | 4.9680 | 7.4520 | 7.4520 | 45.0091 |
| 1,600 | 4.9680 | 7.9488 | 7.9488 | 45.3298 |
| 1,700 | 4.9680 | 8.4456 | 8.4456 | 45.6310 |
| 1,800 | 4.9680 | 8.9424 | 8.9424 | 45.9149 |
| 1,900 | 4.9680 | 9.4392 | 9.4392 | 46.1885 |
| 2,000 | 4.9680 | 9.9360 | 9.9360 | 46.4383 |
| 2,100 | 4.9680 | 10.4328 | 10.4328 | 46.6807 |
| 2,200 | 4.9680 | 10.9296 | 10.9296 | 46.9118 |
| 2,300 | 4.9680 | 11.4264 | 11.4264 | 47.1327 |
| 2,400 | 4.9680 | 11.9232 | 11.9232 | 47.3441 |
| 2,500 | 4.9680 | 12.4200 | 12.4200 | 47.5469 |
| 2,600 | 4.9680 | 12.9168 | 12.9168 | 47.7418 |
| 2,700 | 4.9680 | 13.4136 | 13.4136 | 47.9293 |
| 2,800 | 4.9680 | 13.9104 | 13.9104 | 48.1099 |
| 2,900 | 4.9680 | 14.4072 | 14.4072 | 48.2843 |
| 3,000 | 4.9680 | 14.9040 | 14.9040 | 48.4527 |
| 3,100 | 4.9680 | 15.4008 | 15.4008 | 48.6156 |
| 3,200 | 4.9680 | 15.8976 | 15.8976 | 48.7733 |
| 3,300 | 4.9680 | 16.3944 | 16.3944 | 48.9262 |
| 3,400 | 4.9680 | 16.8912 | 16.8912 | 49.0745 |
| 3,500 | 4.9680 | 17.3880 | 17.3880 | 49.2185 |
| 3,600 | 4.9680 | 17.8848 | 17.8848 | 49.3584 |
| 3,700 | 4.9680 | 18.3816 | 18.3816 | 49.4946 |
| 3,800 | 4.9680 | 18.8784 | 18.8784 | 49.6270 |
| 3,900 | 4.9680 | 19.3752 | 19.3752 | 49.7561 |
| 4,000 | 4.9680 | 19.8720 | 19.8720 | 49.8819 |
| 4,100 | 4.9680 | 20.3688 | 20.3688 | 50.0045 |
| 4,200 | 4.9680 | 20.8656 | 20.8656 | 50.1243 |
| 4,300 | 4.9680 | 21.3624 | 21.3624 | 50.2412 |
| 4,400 | 4.9680 | 21.8592 | 21.8592 | 50.3554 |
| 4,500 | 4.9680 | 22.3560 | 22.3560 | 50.4670 |
| 4,600 | 4.9680 | 22.8528 | 22.8528 | 50.5763 |
| 4,700 | 4.9680 | 23.3496 | 23.3496 | 50.6831 |
| 4,800 | 4.9680 | 23.8464 | 23.8464 | 50.7876 |
| 4,900 | 4.9680 | 24.3432 | 24.3432 | 50.8901 |
| 5,000 | 4.9680 | 24.8400 | 24.8400 | 50.9905 |
| 5,100 | 4.9680 | 25.3368 | 25.3368 | 51.0888 |
| 5,200 | 4.9680 | 25.8336 | 25.8336 | 51.1853 |
| 5,300 | 4.9680 | 26.3304 | 26.3304 | 51.2799 |
| 5,400 | 4.9680 | 26.8272 | 26.8272 | 51.3728 |
| 5,500 | 4.9680 | 27.3240 | 27.3240 | 51.4639 |
| 5,600 | 4.9680 | 27.8208 | 27.8208 | 51.5535 |
| 5,700 | 4.9680 | 28.3176 | 28.3176 | 51.6414 |
| 5,800 | 4.9680 | 28.8144 | 28.8144 | 51.7278 |
| 5,900 | 4.9680 | 29.3112 | 29.3112 | 51.8127 |
| 6,000 | 4.9680 | 29.8080 | 29.8080 | 51.8960 |

## TABLE V—THERMODYNAMIC PROPERTIES OF Al (GAS)

[Atomic weight, 26.97]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ |
|---|---|---|---|---|
| 0 | ---------- | 0 | 300.5416 | ---------- |
| 298.16 | 5.1122 | 1.6535 | 302.1951 | 39.3027 |
| 300 | 5.1104 | 1.6629 | 302.2045 | 39.3342 |
| 400 | 5.0469 | 2.1703 | 302.7119 | 40.7943 |
| 500 | 5.0178 | 2.6734 | 303.2150 | 41.9170 |
| 600 | 5.0022 | 3.1743 | 303.7159 | 42.8304 |
| 700 | 4.9929 | 3.6740 | 304.2156 | 43.6007 |
| 800 | 4.9869 | 4.1730 | 304.7146 | 44.2670 |
| 900 | 4.9829 | 4.6715 | 305.2131 | 44.8541 |
| 1000 | 4.9800 | 5.1696 | 305.7112 | 45.3790 |
| 1100 | 4.9778 | 5.6675 | 306.2091 | 45.8535 |
| 1200 | 4.9762 | 6.1652 | 306.7068 | 46.2865 |
| 1300 | 4.9750 | 6.6628 | 307.2044 | 46.6848 |
| 1400 | 4.9740 | 7.1602 | 307.7018 | 47.0534 |
| 1500 | 4.9732 | 7.6576 | 308.1992 | 47.3966 |
| 1600 | 4.9726 | 8.1549 | 308.6965 | 47.7175 |
| 1700 | 4.9720 | 8.6521 | 309.1937 | 48.0190 |
| 1800 | 4.9716 | 9.1493 | 309.6909 | 48.3032 |
| 1900 | 4.9712 | 9.6464 | 310.1880 | 48.5719 |
| 2000 | 4.9709 | 10.1435 | 310.6851 | 48.8269 |
| 2100 | 4.9706 | 10.6406 | 311.1822 | 49.0694 |
| 2200 | 4.9704 | 11.1376 | 311.6792 | 49.3007 |
| 2300 | 4.9702 | 11.6347 | 312.1763 | 49.5216 |
| 2400 | 4.9700 | 12.1317 | 312.6733 | 49.7331 |
| 2500 | 4.9699 | 12.6287 | 313.1703 | 49.9360 |
| 2600 | 4.9698 | 13.1257 | 313.6673 | 50.1309 |
| 2700 | 4.9698 | 13.6226 | 314.1642 | 50.3185 |
| 2800 | 4.9698 | 14.1196 | 314.6612 | 50.4992 |
| 2900 | 4.9699 | 14.6166 | 315.1582 | 50.6736 |
| 3000 | 4.9701 | 15.1136 | 315.6552 | 50.8421 |
| 3100 | 4.9704 | 15.6106 | 316.1522 | 51.0051 |
| 3200 | 4.9709 | 16.1077 | 316.6493 | 51.1629 |
| 3300 | 4.9716 | 16.6048 | 317.1464 | 51.3159 |
| 3400 | 4.9724 | 17.1020 | 317.6436 | 51.4643 |
| 3500 | 4.9736 | 17.5993 | 318.1409 | 51.6085 |
| 3600 | 4.9750 | 18.0968 | 318.6384 | 51.7486 |
| 3700 | 4.9768 | 18.5943 | 319.1359 | 51.8849 |
| 3800 | 4.9791 | 19.0921 | 319.6337 | 52.0177 |
| 3900 | 4.9818 | 19.5902 | 320.1318 | 52.1470 |
| 4000 | 4.9851 | 20.0885 | 320.6301 | 52.2732 |
| 4100 | 4.9890 | 20.5872 | 321.1288 | 52.3964 |
| 4200 | 4.9936 | 21.0864 | 321.6280 | 52.5166 |
| 4300 | 4.9990 | 21.5860 | 322.1276 | 52.6342 |
| 4400 | 5.0052 | 22.0862 | 322.6278 | 52.7492 |
| 4500 | 5.0122 | 22.5871 | 323.1287 | 52.8618 |
| 4600 | 5.0203 | 23.0887 | 323.6303 | 52.9720 |
| 4700 | 5.0294 | 23.5912 | 324.1328 | 53.0801 |
| 4800 | 5.0396 | 24.0946 | 324.6362 | 53.1861 |
| 4900 | 5.0510 | 24.5992 | 325.1408 | 53.2901 |
| 5000 | 5.0637 | 25.1049 | 325.6465 | 53.3923 |
| 5100 | 5.0776 | 25.6120 | 326.1536 | 53.4927 |
| 5200 | 5.0928 | 26.1205 | 326.6621 | 53.5914 |
| 5300 | 5.1094 | 26.6306 | 327.1722 | 53.6886 |
| 5400 | 5.1275 | 27.1424 | 327.6840 | 53.7843 |
| 5500 | 5.1470 | 27.6562 | 328.1978 | 53.8785 |
| 5600 | 5.1680 | 28.1719 | 328.7135 | 53.9714 |
| 5700 | 5.1905 | 28.6898 | 329.2314 | 54.0631 |
| 5800 | 5.2145 | 29.2101 | 329.7517 | 54.1536 |
| 5900 | 5.2401 | 29.7328 | 330.2744 | 54.2430 |
| 6000 | 5.2672 | 30.2582 | 330.7998 | 54.3313 |

## TABLE VI.—THERMODYNAMIC PROPERTIES OF Al (CRYSTAL)

[Atomic weight, 26.97]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ-H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | log $K$ |
|---|---|---|---|---|---|---|
| 0 | -------- | 0 | 233.6251 | -------- | -------- | -------- |
| 298.16 | 5.80 | 1.0700 | 234.6951 | 6.641 | 113.9245 | 42.3386 |
| 300 | 5.81 | 1.0820 | 234.7071 | 6.682 | 113.2214 | 42.0354 |
| 400 | 6.24 | 1.6860 | 235.3111 | 8.819 | 84.7945 | 29.7284 |
| 500 | 6.46 | 2.3210 | 235.9461 | 9.844 | 67.7029 | 22.3935 |
| 600 | 6.66 | 2.9760 | 236.6011 | 11.013 | 56.2898 | 17.4927 |
| 700 | 6.88 | 3.6530 | 237.2781 | 12.070 | 48.1210 | 14.0077 |
| 800 | 7.15 | 4.3530 | 237.9781 | 13.018 | 41.9794 | 11.4020 |
| 900 | 7.65 | 5.0890 | 238.7141 | 13.864 | 37.1822 | 9.3752 |
| 930 | 7.90 | 5.3240 | 238.9491 | 14.130 | 35.9365 | 8.8566 |

## TABLE VII—THERMODYNAMIC PROPERTIES OF Al (LIQUID)

[Atomic weight, 26.97]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ-H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 930 | 6.75 | 7.8240 | 241.4491 | 16.818 | 34.5838 | -------- | -------- | 8.8566 | -------- | -------- |
| 1000 | 6.84 | 8.2990 | 241.9241 | 17.310 | 32.0993 | 3271 | 0.03246 | 7.8061 | 1414 | −0.01995 |
| 1100 | 6.966 | 8.9893 | 242.6144 | 17.9078 | 29.0932 | 2974 | 0.03217 | 6.5406 | 1285 | −0.01953 |
| 1200 | 7.092 | 9.6922 | 243.3173 | 18.5704 | 26.5827 | 2726 | .03228 | 5.4893 | 1178 | −.01955 |
| 1300 | 7.218 | 10.4077 | 244.0328 | 19.1520 | 24.4535 | 2517 | .03174 | 4.6027 | 1087 | −.01923 |
| 1400 | 7.344 | 11.1358 | 244.7609 | 19.6915 | 22.6239 | 2337 | .03190 | 3.8455 | 1009 | −.01887 |
| 1500 | 7.470 | 11.8765 | 245.5016 | 20.2025 | 21.0340 | 2181 | .03198 | 3.1917 | 941 | −.01832 |
| 1600 | 7.596 | 12.6298 | 246.2549 | 20.6886 | 19.6389 | 2045 | 0.03186 | 2.6219 | 882 | −0.01812 |
| 1700 | 7.722 | 13.3957 | 247.0208 | 21.1529 | 18.4041 | 1925 | .03165 | 2.1212 | 830 | −.01811 |
| 1800 | 7.848 | 14.1742 | 247.7993 | 21.5978 | 17.3030 | 1818 | .03166 | 1.6782 | 784 | −.01803 |
| 1900 | 7.974 | 14.9653 | 248.5904 | 22.0255 | 16.3145 | 1722 | .03190 | 1.2836 | 742 | −.01760 |
| 2000 | 8.100 | 15.7690 | 249.3941 | 22.4377 | 15.4210 | 1636 | .03175 | .9302 | 705 | −.01751 |
| 2100 | 8.226 | 16.5853 | 250.2104 | 22.8360 | 14.6108 | 1558 | 0.03192 | 0.6120 | 671 | −0.01740 |
| 2200 | 8.352 | 17.4142 | 251.0393 | 23.2216 | 13.8707 | 1487 | .03188 | .3244 | 640 | −.01706 |
| 2300 | 8.478 | 18.1857 | 251.8808 | 23.5956 | 13.1923 | 1423 | .03168 | .0632 | 612 | −.01700 |
| 2400 | 8.604 | 19.1098 | 252.7349 | 23.9591 | 12.5677 | 1363 | .03190 | −.1748 | 586 | −.01670 |
| 2500 | 8.730 | 19.9765 | 253.6016 | 24.3129 | 11.9906 | 1309 | .03174 | −.3925 | 562 | −.01655 |
| 2600 | 8.856 | 20.8558 | 254.4809 | 24.6577 | 11.4554 | 1259 | 0.03160 | −0.5921 | 540 | −0.01630 |
| 2700 | 8.982 | 21.7477 | 255.3728 | 24.9943 | 10.9575 | 1212 | .03164 | −.7758 | 520 | −.01631 |
| 2800 | 9.108 | 22.6522 | 256.2773 | 25.3233 | 10.4930 | 1169 | .03170 | −.9452 | 501 | −.01616 |
| 2900 | 9.234 | 23.5693 | 257.1944 | 25.6451 | 10.0582 | 1129 | .03147 | −1.1018 | 483 | −.01600 |
| 3000 | 9.360 | 24.4990 | 258.1241 | 25.9602 | 9.6504 | -------- | -------- | −1.2468 | -------- | -------- |

## TABLE VIII—THERMODYNAMIC PROPERTIES OF AlO (GAS)

[Molecular weight, 42.97]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | $\log K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | ---------- | 0 | 272.4501 | ---------- | ---------- | -------- | ---------- | ---------- | -------- | ---------- |
| 298.16 | 7.3749 | 2.1005 | 274.5506 | 52.1648 | 149.9685 | -------- | ---------- | 59.5342 | -------- | ---------- |
| 300 | 7.3820 | 2.1140 | 274.5641 | 52.2101 | 148.0580 | -------- | ---------- | 59.1348 | -------- | ---------- |
| 400 | 7.7510 | 2.8711 | 275.3212 | 54.3856 | 112.1309 | -------- | ---------- | 42.9281 | -------- | ---------- |
| 500 | 8.0424 | 3.6615 | 276.1116 | 56.1482 | 89.9293 | -------- | ---------- | 33.1770 | -------- | ---------- |
| 600 | 8.2530 | 4.4769 | 276.9270 | 57.6342 | 75.1020 | -------- | ---------- | 26.6609 | -------- | ---------- |
| 700 | 8.4035 | 5.3101 | 277.7602 | 58.9183 | 64.4956 | -------- | ---------- | 21.9971 | -------- | ---------- |
| 800 | 8.5122 | 6.1562 | 278.6063 | 60.0479 | 56.5311 | -------- | ---------- | 18.4930 | -------- | ---------- |
| 900 | 8.5924 | 7.0116 | 279.4617 | 61.0553 | 50.3305 | -------- | ---------- | 15.7629 | -------- | ---------- |
| 1000 | 8.6529 | 7.8740 | 280.3241 | 61.9639 | 45.3658 | 4456 | 0.01879 | 13.5755 | 1955 | 0.01513 |
| 1100 | 8.6993 | 8.7416 | 281.1917 | 62.7908 | 41.3011 | 4054 | 0.01097 | 11.7831 | 1779 | 0.01320 |
| 1200 | 8.7356 | 9.6134 | 282.0635 | 63.5493 | 37.9118 | 3719 | .00853 | 10.2874 | 1632 | .01202 |
| 1300 | 8.7645 | 10.4884 | 282.9385 | 64.2496 | 35.0425 | 3435 | .00693 | 9.0200 | 1508 | .01056 |
| 1400 | 8.7878 | 11.3660 | 283.8161 | 64.9000 | 32.5820 | 3191 | .00597 | 7.9323 | 1402 | .00923 |
| 1500 | 8.8069 | 12.2457 | 284.6958 | 65.5070 | 30.4487 | 2980 | .00470 | 6.9884 | 1309 | .00888 |
| 1600 | 8.8227 | 13.1272 | 285.5773 | 66.0759 | 28.5815 | 2795 | 0.00388 | 6.1614 | 1228 | 0.00825 |
| 1700 | 8.8359 | 14.0101 | 286.4602 | 66.6111 | 26.9335 | 2632 | .00308 | 5.4308 | 1157 | .00752 |
| 1800 | 8.8471 | 14.8943 | 287.3444 | 67.1165 | 25.4682 | 2487 | .00245 | 4.7805 | 1094 | .00671 |
| 1900 | 8.8566 | 15.7795 | 288.2296 | 67.5951 | 24.1568 | 2357 | .00190 | 4.1960 | 1037 | .00630 |
| 2000 | 8.8647 | 16.6655 | 289.1156 | 68.0496 | 22.9764 | 2240 | .00163 | 3.6732 | 986 | .00593 |
| 2100 | 8.8718 | 17.5524 | 290.0025 | 68.4822 | 21.9081 | 2134 | 0.00130 | 3.1977 | 940 | 0.00543 |
| 2200 | 8.8779 | 18.4399 | 290.8900 | 68.8951 | 20.9368 | 2037 | .00115 | 2.7650 | 898 | .00517 |
| 2300 | 8.8833 | 19.3279 | 291.7780 | 69.2899 | 20.0500 | 1949 | .00102 | 2.3694 | 859 | .00508 |
| 2400 | 8.8880 | 20.2165 | 292.6666 | 69.6680 | 19.2369 | 1869 | .00050 | 2.0064 | 824 | .00480 |
| 2500 | 8.8922 | 21.1055 | 293.5556 | 70.0309 | 18.4888 | 1795 | .00022 | 1.6720 | 791 | .00477 |
| 2600 | 8.8960 | 21.9949 | 294.4450 | 70.3798 | 17.7962 | 1727 | −0.00013 | 1.3630 | 761 | 0.00455 |
| 2700 | 8.8993 | 22.8847 | 295.3348 | 70.7156 | 17.1587 | 1663 | −.00023 | 1.0768 | 734 | .00416 |
| 2800 | 8.9023 | 23.7747 | 296.2248 | 71.0393 | 16.5650 | 1605 | −.00065 | .8103 | 708 | .00406 |
| 2900 | 8.9050 | 24.6651 | 297.1152 | 71.3517 | 16.0122 | 1550 | −.00087 | .5621 | 684 | .00390 |
| 3000 | 8.9074 | 25.5557 | 298.0058 | 71.6536 | 15.4964 | 1500 | −.00127 | .3302 | 662 | .00375 |
| 3100 | 8.9096 | 26.4466 | 298.8967 | 71.9458 | 15.0138 | 1452 | −0.00145 | 0.1129 | 640 | 0.00380 |
| 3200 | 8.9116 | 27.3376 | 299.7877 | 72.2287 | 14.5615 | 1407 | −.00156 | −.0909 | 621 | .00362 |
| 3300 | 8.9134 | 28.2289 | 300.6790 | 72.5029 | 14.1367 | 1365 | −.00177 | −.2827 | 602 | .00364 |
| 3400 | 8.9150 | 29.1203 | 301.5704 | 72.7690 | 13.7370 | 1326 | −.00216 | −.4634 | 584 | .00364 |
| 3500 | 8.9166 | 30.0119 | 302.4620 | 73.0275 | 13.3608 | 1289 | −.00236 | −.6339 | 568 | .00352 |
| 3600 | 8.9180 | 30.9036 | 303.3537 | 73.2787 | 13.0046 | 1254 | −0.00252 | −0.7952 | 552 | 0.00351 |
| 3700 | 8.9193 | 31.7955 | 304.2456 | 73.5230 | 12.6682 | 1221 | −.00282 | −.9479 | 538 | .00332 |
| 3800 | 8.9205 | 32.6875 | 305.1376 | 73.7609 | 12.3497 | 1190 | −.00313 | −1.0928 | 524 | .00324 |
| 3900 | 8.9216 | 33.5796 | 306.0297 | 73.9927 | 12.0477 | 1160 | −.00320 | −1.2304 | 511 | .00315 |
| 4000 | 8.9226 | 34.4718 | 306.9219 | 74.2186 | 11.7609 | 1132 | −.00350 | −1.3613 | 498 | .00314 |
| 4100 | 8.9235 | 35.3641 | 307.8142 | 74.4389 | 11.4883 | 1106 | −0.00393 | −1.4859 | 486 | 0.00319 |
| 4200 | 8.9244 | 36.2565 | 308.7066 | 74.6539 | 11.2289 | 1081 | −.00420 | −1.6048 | 475 | .00303 |
| 4300 | 8.9252 | 37.1490 | 309.5991 | 74.8639 | 10.9817 | 1057 | −.00443 | −1.7183 | 464 | .00295 |
| 4400 | 8.9260 | 38.0415 | 310.4916 | 75.0691 | 10.7459 | 1034 | −.00468 | −1.8267 | 454 | .00291 |
| 4500 | 8.9267 | 38.9342 | 311.3843 | 75.2697 | 10.5208 | 1012 | −.00490 | −1.9305 | 444 | .00288 |
| 4600 | 8.9274 | 39.8269 | 312.2770 | 75.4659 | 10.3057 | 991 | −0.00515 | −2.0299 | 434 | 0.00296 |
| 4700 | 8.9280 | 40.7196 | 313.1697 | 75.6579 | 10.1000 | 972 | −.00560 | −2.1252 | 425 | .00286 |
| 4800 | 8.9286 | 41.6125 | 314.0626 | 75.8459 | 9.9031 | 953 | −.00579 | −2.2166 | 416 | .00300 |
| 4900 | 8.9291 | 42.5054 | 314.9555 | 76.0300 | 9.7144 | 935 | −.00610 | −2.3045 | 407 | .00300 |
| 5000 | 8.9296 | 43.3983 | 315.8484 | 76.2104 | 9.5335 | 918 | −.00650 | −2.3889 | 400 | .00287 |
| 5100 | 8.9301 | 44.2913 | 316.7414 | 76.3873 | 9.3600 | 901 | −0.00667 | −2.4702 | 391 | 0.00301 |
| 5200 | 8.9306 | 45.1843 | 317.6344 | 76.5607 | 9.1934 | 886 | −.00707 | −2.5484 | 384 | .00295 |
| 5300 | 8.9310 | 46.0774 | 318.5275 | 76.7308 | 9.0333 | 871 | −.00740 | −2.6238 | 377 | .00289 |
| 5400 | 8.9314 | 46.9705 | 319.4206 | 76.8977 | 8.8794 | 857 | −.00782 | −2.6965 | 369 | .00301 |
| 5500 | 8.9318 | 47.8687 | 320.3138 | 77.0616 | 8.7314 | 843 | −.00814 | −2.7666 | 363 | .00298 |
| 5600 | 8.9322 | 48.7569 | 321.2070 | 77.2226 | 8.5890 | 830 | −0.00851 | −2.8344 | 356 | 0.00304 |
| 5700 | 8.9326 | 49.6501 | 322.1002 | 77.3807 | 8.4519 | 817 | −.00876 | −2.8999 | 349 | .00313 |
| 5800 | 8.9329 | 50.5434 | 322.9935 | 77.5360 | 8.3198 | 805 | −.00904 | −2.9632 | 343 | .00316 |
| 5900 | 8.9332 | 51.4367 | 323.8868 | 77.6887 | 8.1924 | 793 | −.00947 | −3.0245 | 337 | .00323 |
| 6000 | 8.9335 | 52.3300 | 324.7801 | 77.8389 | 8.0697 | -------- | ---------- | −3.0839 | -------- | ---------- |

TABLE IX—THERMODYNAMIC PROPERTIES OF $Al_2O_3$ (CRYSTAL, $\alpha$)

[Molecular weight, 101.94]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_{1000}^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta-\left(\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ $a$ | $b$ | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ $c$ | $d$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| 298.16 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| 300 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| 400 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| 500 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| 600 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| 700 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| 800 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| 900 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| 1000 | 23.360 | 0 | 237.0838 | 91.5490 | 286.1479 | 28,430 | 0.10445 | 95.1916 | 12,409 | 0.01799 |
| 1100 | 23.754 | 2.3557 | 239.4395 | 93.7939 | 260.1980 | 25,870 | 0.08207 | 83.8927 | 11,287 | 0.01187 |
| 1200 | 24.064 | 4.7466 | 241.8304 | 95.8741 | 238.5576 | 23,735 | .06471 | 74.4750 | 10,351 | .00779 |
| 1300 | 24.311 | 7.1654 | 244.2492 | 97.8100 | 220.2352 | 21,925 | .05269 | 66.5049 | 9,558 | .00516 |
| 1400 | 24.510 | 9.6064 | 246.6902 | 99.6189 | 204.5218 | 20,373 | .04250 | 59.6726 | 8,878 | .00293 |
| 1500 | 24.672 | 12.0655 | 249.1493 | 101.3154 | 190.8973 | 19,026 | .03505 | 53.7510 | 8,268 | .00170 |
| 1600 | 24.806 | 14.5394 | 251.6232 | 102.9120 | 178.9710 | 17,846 | 0.02935 | 48.5693 | 7,771 | 0.00092 |
| 1700 | 24.916 | 17.0254 | 254.1092 | 104.4191 | 168.4440 | 16,805 | .02429 | 43.9972 | 7,315 | .00021 |
| 1800 | 25.010 | 19.5217 | 256.6055 | 105.8459 | 159.0836 | 15,878 | .02056 | 39.9331 | 6,910 | −.00054 |
| 1900 | 25.090 | 22.0267 | 259.1105 | 107.2003 | 150.7062 | 15,048 | .01760 | 36.2968 | 6,547 | −.00100 |
| 2000 | 25.159 | 24.5392 | 261.6230 | 108.4890 | 143.1646 | 14,300 | .01538 | 33.0243 | 6,220 | −.00130 |
| 2100 | 25.221 | 27.0582 | 264.1420 | 109.7180 | 136.3397 | 13,623 | 0.01353 | 30.0637 | 5,924 | −0.00133 |
| 2200 | 25.277 | 29.5831 | 266.6669 | 110.8925 | 130.1339 | 13,008 | .01165 | 27.3723 | 5,656 | −.00160 |
| 2300 | 25.329 | 32.1134 | 269.1972 | 112.0173 | 124.4666 | 12,447 | .00965 | 24.9152 | 5,410 | −.00197 |
| 2400 | 25.374 | 34.6485 | 271.7323 | 113.0962 | 119.2707 | 11,933 | .00780 | 22.6630 | 5,185 | −.00210 |
| 2500 | 25.408 | 37.1876 | 274.2714 | 114.1327 | 114.4897 | 11,460 | .00601 | 20.5911 | 4,977 | −.00193 |

TABLE X—THERMODYNAMIC PROPERTIES OF $Al_2O_3$ (GAS)

[Molecular weight, 101.94]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_{298.16}^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ $a$ | $b$ | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ $c$ | $d$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 298.16 | 18.8144 | 0 | 76.4666 | 12.5 | 1200.9468 | -------- | ---------- | 481.8955 | -------- | ---------- |
| 300 | 18.9368 | 0.0347 | 76.5013 | 12.6160 | 1193.6027 | -------- | ---------- | 478.6965 | -------- | ---------- |
| 400 | 23.3603 | 2.1790 | 78.6456 | 18.7545 | 895.7357 | -------- | ---------- | 349.0606 | -------- | ---------- |
| 500 | 25.5720 | 4.6362 | 81.1028 | 24.2285 | 716.6696 | -------- | ---------- | 271.2518 | -------- | ---------- |
| 600 | 26.9132 | 7.2651 | 83.7317 | 29.0179 | 597.1339 | -------- | ---------- | 219.3803 | -------- | ---------- |
| 700 | 27.8434 | 10.0054 | 86.4720 | 33.2403 | 511.6641 | -------- | ---------- | 182.3381 | -------- | ---------- |
| 800 | 28.5546 | 12.8266 | 89.2932 | 37.0064 | 447.5067 | -------- | ---------- | 154.5672 | -------- | ---------- |
| 900 | 29.1383 | 15.7121 | 92.1787 | 40.4041 | 397.5684 | -------- | ---------- | 132.9781 | -------- | ---------- |
| 1000 | 29.6430 | 18.6517 | 95,1183 | 43.5010 | 357.5885 | 35,876 | 0.11665 | 115.7171 | 15,581 | −0.05115 |
| 1100 | 30.0960 | 21.6386 | 98.1052 | 46.3475 | 324.8553 | 32,625 | 0.10920 | 101.6037 | 14,164 | −0.05063 |
| 1200 | 30.5138 | 24.6691 | 101.1357 | 48.9841 | 297.5586 | 29,915 | .10186 | 89.8510 | 12,984 | −.05099 |
| 1300 | 30.9068 | 27.7401 | 104.2067 | 51.4421 | 274.4452 | 27,620 | .09723 | 79.9143 | 11,984 | −.05000 |
| 1400 | 31.2819 | 30.8496 | 107.3162 | 53.7462 | 254.6194 | 25,653 | .09290 | 71.4043 | 11,127 | −.04940 |
| 1500 | 31.6436 | 33.9958 | 110.4624 | 55.9168 | 237.4245 | 23,948 | .08950 | 64.0357 | 10,385 | −.04913 |
| 1600 | 31.9951 | 37.1778 | 113.6444 | 57.9702 | 222.3675 | 22,454 | 0.08777 | 57.5942 | 9,735 | −0.04857 |
| 1700 | 32.3389 | 40.3945 | 116.8611 | 59.9202 | 209.0715 | 21,137 | .08562 | 51.9163 | 9,161 | −.04774 |
| 1800 | 32.6766 | 43.6452 | 120.1118 | 61.7782 | 197.2431 | 19,965 | .08421 | 46.8746 | 8,652 | −.04769 |
| 1900 | 33.0094 | 46.9295 | 123.3961 | 63.5539 | 186.6510 | 18,917 | .08300 | 42.3686 | 8,196 | −.04720 |
| 2000 | 33.3383 | 50.2469 | 126.7135 | 65.2554 | 177.1095 | 17,973 | .08183 | 38.3178 | 7,785 | −.04664 |
| 2100 | 33.6639 | 53.5970 | 130.0636 | 66.8899 | 168.4691 | 17,119 | 0.08114 | 34.6573 | 7,412 | −0.04549 |
| 2200 | 33.9870 | 56.9796 | 133.4462 | 68.4634 | 160.6066 | 16,343 | .07995 | 31.3337 | 7,074 | −.04495 |
| 2300 | 34.3079 | 60.3943 | 136.8609 | 69.9812 | 153.4210 | 15,634 | .07958 | 28.3030 | 6,762 | −.04294 |
| 2319.57 | 34.3704 | 61.0663 | 137.5329 | 70.2722 | 152.0864 | -------- | ---------- | 27.7409 | -------- | ---------- |
| 2600 | 25.439 | 39.7300 | 276.8138 | 115.1299 | 110.0760 | 11,024 | 0.00414 | 18.6788 | 4,736 | −0.00209 |
| 2700 | 25.466 | 42.2752 | 279.3590 | 116.0905 | 105.9889 | 10,619 | .00300 | 16.9083 | 4,608 | −.00191 |
| 2800 | 25.491 | 44.8231 | 281.9069 | 117.0170 | 102.1934 | 10,243 | .00183 | 15.2645 | 4,444 | −.00201 |
| 2900 | 25.514 | 47.3733 | 284.4571 | 117.9120 | 98.6595 | 9,892 | .00107 | 13.7341 | 4,291 | −.00213 |
| 3000 | 25.534 | 49.9257 | 287.0095 | 118.7773 | 95.3611 | 9,565 | .00012 | 12.3059 | 4,148 | −.00216 |
| 3100 | 25.552 | 52.4800 | 289.5638 | 119.6148 | 92.2755 | 9,260 | −0.00105 | 10.9700 | 4,014 | −0.00218 |
| 3200 | 25.570 | 55.0361 | 292.1199 | 120.4263 | 89.3828 | 8,974 | −.00209 | 9.7178 | 3,889 | −.00218 |
| 3300 | 25.585 | 57.5939 | 294.6777 | 121.2134 | 86.6655 | 8,705 | −.00299 | 8.5415 | 3,770 | −.00192 |
| 3400 | 25.599 | 60.1531 | 297.2369 | 121.9774 | 84.1082 | 8,452 | −.00386 | 7.4346 | 3,659 | −.00183 |
| 3500 | 25.613 | 62.7137 | 299.7975 | 122.7197 | 81.6972 | 8,214 | −.00487 | 6.8910 | 3,555 | −.00190 |
| 3600 | 25.624 | 65.2755 | 302.3593 | 123.4414 | 79.4804 | 7,988 | −0.00542 | 5.4054 | 3,455 | −0.00168 |
| 3700 | 25.635 | 67.8385 | 304.9223 | 124.1436 | 77.2669 | 7,774 | −.00599 | 4.4733 | 3,362 | −.00164 |
| 3800 | 25.645 | 70.4025 | 307.4863 | 124.8273 | 75.2271 | 7,572 | −.00664 | 3.5902 | 3,273 | −.00163 |
| 3900 | 25.655 | 72.9675 | 310.0513 | 125.4936 | 73.2922 | 7,381 | −.00745 | 2.7526 | 3,189 | −.00145 |
| 4000 | 25.663 | 75.5334 | 312.6172 | 126.1432 | 71.4544 | 7,199 | −.00815 | 1.9568 | 3,109 | −.00149 |
| 4100 | 25.671 | 78.1001 | 315.1839 | 126.7770 | 69.7067 | 7,027 | −0.00899 | 1.2000 | 3,033 | −0.00134 |
| 4200 | 25.679 | 80.6676 | 317.7514 | 127.3957 | 68.0426 | 6,863 | −.00985 | .4792 | 2,960 | −.00117 |
| 4300 | 25.687 | 83.2359 | 320.3197 | 128.0091 | 66.4564 | 6,707 | −.01062 | −.2080 | 2,890 | −.00092 |
| 4400 | 25.693 | 85.8049 | 322.8887 | 128.5907 | 64.9427 | 6,557 | −.01111 | −.8639 | 2,824 | −.00076 |
| 4500 | 25.699 | 88.3745 | 325.4583 | 129.1681 | 63.4967 | 6,414 | −.01185 | −1.4907 | 2,761 | −.00073 |
| 4600 | 25.705 | 90.9447 | 328.0285 | 129.7330 | 62.1142 | 6,278 | −0.01244 | −2.0902 | 2,700 | −0.00057 |
| 4700 | 25.710 | 93.5154 | 330.5992 | 130.2859 | 60.7909 | 6,147 | −.01313 | −2.6641 | 2,642 | −.00042 |
| 4800 | 25.716 | 96.0867 | 333.1705 | 130.8273 | 59.5234 | 6,023 | −.01388 | −3.2141 | 2,587 | −.00036 |
| 4900 | 25.720 | 98.6585 | 335.7423 | 131.3575 | 58.3081 | 5,903 | −.01440 | −3.7417 | 2,533 | −.00020 |
| 5000 | 25.725 | 101.2308 | 338.3146 | 131.8772 | 57.1419 | 5,788 | −.01510 | −4.2481 | 2,482 | −.00007 |
| 5100 | 25.729 | 103.8035 | 340.8873 | 132.3867 | 56.0221 | 5,678 | −0.01582 | −4.7347 | 2,433 | 0.00002 |
| 5200 | 25.733 | 106.3766 | 343.4604 | 132.8863 | 54.9460 | 5,572 | −.01642 | −5.2026 | 2,385 | .00030 |
| 5300 | 25.737 | 108.9501 | 346.0339 | 133.3765 | 53.9111 | 5,471 | −.01715 | −5.6529 | 2,339 | .00045 |
| 5400 | 25.741 | 111.5240 | 348.6078 | 133.8576 | 52.9151 | 5,373 | −.01781 | −6.0865 | 2,294 | .00071 |
| 5500 | 25.745 | 114.0983 | 351.1821 | 134.3300 | 51.9560 | 5,279 | −.01838 | −6.5043 | 2,252 | .00086 |
| 5600 | 25.748 | 116.6729 | 353.7567 | 134.7939 | 51.0317 | 5,188 | −0.01908 | −6.9073 | 2,211 | 0.00091 |
| 5700 | 25.752 | 119.2479 | 356.3317 | 135.2497 | 50.1406 | 5,100 | −.01961 | −7.2961 | 2,172 | .00102 |
| 5800 | 25.756 | 121.8233 | 358.9071 | 135.6976 | 49.2809 | 5,016 | −.02017 | −7.6716 | 2,133 | .00117 |
| 5900 | 25.760 | 124.3991 | 361.4829 | 136.1379 | 48.4509 | 4,935 | −.02100 | −8.0343 | 2,096 | .00137 |
| 6000 | 25.763 | 126.9753 | 364.0591 | 136.5709 | 47.6494 | -------- | ---------- | −8.3850 | -------- | ---------- |

TABLE XI—THERMODYNAMIC PROPERTIES OF $Al_2O_3$ (LIQUID)

[Molecular weight, 101.94]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_{298.16}^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ (a) | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ $a$ | $b$ | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ $c$ | $d$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 2319.57 | 35.79 | 67.0670 | 143.5336 | 72.8593 | 150.7846 | 15,518 | 0.04937 | 27.7409 | 6,666 | −0.05066 |
| 2400 | 35.95 | 69.9520 | 146.4186 | 74.0819 | 145.5461 | 14,995 | .04850 | 25.5477 | 6,441 | −.05000 |
| 2500 | 36.15 | 73.5570 | 150.0236 | 75.5535 | 139.4996 | 14,396 | .04828 | 23.0213 | 6,181 | −.04911 |
| 2600 | 36.35 | 77.1820 | 153.6486 | 76.9753 | 133.9144 | 13.844 | 0.04759 | 20.6931 | 5.941 | −0.04807 |
| 2700 | 36.55 | 80.8270 | 157.2936 | 78.3509 | 128.7394 | 13,332 | .04737 | 18.5408 | 5,718 | −.04704 |
| 2800 | 36.75 | 84.4920 | 160.9586 | 79.6837 | 123.9306 | 12,858 | .04651 | 16.5457 | 5,512 | −.04629 |
| 2900 | 36.95 | 88.1770 | 164.6436 | 80.9768 | 119.4503 | 12,416 | .04603 | 14.6913 | 5,319 | −.04530 |
| 3000 | 37.15 | 91.8820 | 168.3486 | 82.2329 | 115.2656 | 12,004 | .04554 | 12.9636 | 5,140 | −.04466 |
| 3100 | 37.35 | 95.6070 | 172.0736 | 83.4543 | 111.3478 | 11,618 | 0.04506 | 11.3502 | 4,972 | −0.04395 |
| 3200 | 37.55 | 99.3520 | 175.8186 | 84.6432 | 107.6721 | 11,257 | .04439 | 9.8404 | 4,814 | −.04309 |
| 3300 | 37.75 | 103.1170 | 179.5836 | 85.8018 | 104.2165 | 10,918 | .04372 | 8.4247 | 4,666 | −.04235 |
| 3400 | 37.95 | 106.9020 | 183.3686 | 86.9317 | 100.9616 | 10,599 | .04322 | 7.0947 | 4,526 | −.04154 |
| 3500 | 38.15 | 110.7070 | 187.1736 | 88.0347 | 97.8901 | 10,298 | .04264 | 5.8431 | 4,395 | −.04103 |
| 3600 | 38.35 | 114.5320 | 190.9986 | 89.1122 | 94.9869 | 10,013 | 0.04228 | 4.6683 | 4,271 | −0.04052 |
| 3700 | 38,55 | 118.3770 | 194.8436 | 90.1657 | 92.2384 | 9,745 | .04163 | 3.5495 | 4,153 | −.03979 |
| 3800 | 38.75 | 122.2420 | 198.7086 | 91.1964 | 89.6323 | 9,491 | .04101 | 2.4964 | 4,042 | −.03921 |
| 3900 | 38.95 | 126.1270 | 202.5936 | 92.2055 | 87.1577 | 9,250 | 04040 | 1.4992 | 3,936 | −.03870 |
| 4000 | 39.15 | 130.0320 | 206.4986 | 93.1942 | 84.8048 | -------- | ---------- | .5539 | -------- | ---------- |

(a) Enthalpy change in converting $Al_2O_3$ (crystal, $\alpha$) at 298.16° to $Al_2O_3$ (liquid) at temperature indicated.

## TABLE XII—THERMODYNAMIC PROPERTIES OF B (GAS)

[Atomic weight, 10.82]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ-H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ |
|---|---|---|---|---|
| 0 | ------ | 0 | 269.0696 | ------- |
| 298.16 | 4.9704 | 1.5097 | 270.5793 | 36.0493 |
| 300 | 4.9704 | 1.5188 | 270.5884 | 36.0798 |
| 400 | 4.9693 | 2.0158 | 271.0854 | 38.1096 |
| 500 | 4.9688 | 2.5127 | 271.5823 | 39.2183 |
| 600 | 4.9686 | 3.0096 | 272.0792 | 40.1243 |
| 700 | 4.9684 | 3.5064 | 272.5700 | 40.8902 |
| 800 | 4.9683 | 4.0033 | 273.0729 | 41.5536 |
| 900 | 4.9682 | 4.5001 | 273.5697 | 42.1388 |
| 1000 | 4.9682 | 4.9969 | 274.0665 | 42.6625 |
| 1100 | 4.9682 | 5.4937 | 274.5633 | 43.1360 |
| 1200 | 4.9681 | 5.9905 | 275.0001 | 43.5683 |
| 1300 | 4.9681 | 6.4874 | 275.5570 | 43.9659 |
| 1400 | 4.9681 | 6.9842 | 276.0538 | 44.3341 |
| 1500 | 4.9681 | 7.4810 | 276.5506 | 44.6769 |
| 1600 | 4.9681 | 7.9778 | 277.0474 | 44.9975 |
| 1700 | 4.9681 | 8.4746 | 277.5442 | 45.2987 |
| 1800 | 4.9680 | 8.9714 | 278.0410 | 45.5827. |
| 1900 | 4.9680 | 9.4682 | 278.5378 | 45.8513 |
| 2000 | 4.9680 | 9.9650 | 279.0346 | 46.1061 |
| 2100 | 4.9680 | 10.4618 | 279.5314 | 46.3485 |
| 2200 | 4.9680 | 10.9586 | 280.0282 | 46.5796 |
| 2300 | 4.9680 | 11.4554 | 280.5250 | 46.8004 |
| 2400 | 4.9680 | 11.9522 | 281.0218 | 47.0119 |
| 2500 | 4.9680 | 12.4490 | 281.5186 | 47.2147 |
| 2600 | 4.9680 | 12.9458 | 282.0154 | 47.4095 |
| 2700 | 4.9680 | 13.4426 | 282.5122 | 47.5970 |
| 2800 | 4.9680 | 13.9394 | 283.0090 | 47.7777 |
| 2900 | 4.9680 | 14.4362 | 283.5058 | 47.9520 |
| 3000 | 4.6980 | 14.9330 | 284.0026 | 48.1204 |
| 3100 | 4.9680 | 15.4298 | 284.4994 | 48.2833 |
| 3200 | 4.9680 | 15.9266 | 284.9962 | 48.4410 |
| 3300 | 4.9680 | 16.4234 | 285.4930 | 48.5939 |
| 3400 | 4.9680 | 16.9202 | 285.9898 | 48.7422 |
| 3500 | 4.9680 | 17.4170 | 286.4866 | 48.8862 |
| 3600 | 4.9680 | 17.9138 | 286.9834 | 49.0262 |
| 3700 | 4.9680 | 18.4106 | 287.4802 | 49.1623 |
| 3800 | 4.9680 | 18.9074 | 287.9770 | 49.2948 |
| 3900 | 4.9680 | 19.4042 | 288.4738 | 49.4238 |
| 4000 | 4.9681 | 19.9010 | 288.9706 | 49.5496 |
| 4100 | 4.9681 | 20.3978 | 289.4674 | 49.6723 |
| 4200 | 4.9681 | 20.8946 | 289.9642 | 49.7920 |
| 4300 | 4.9682 | 21.3914 | 290.4610 | 49.9089 |
| 4400 | 4.9682 | 21.8883 | 290.9579 | 50.0231 |
| 4500 | 4.9683 | 22.8851 | 291.4547 | 50.1348 |
| 4600 | 4.9685 | 22.8819 | 291.9515 | 50.2440 |
| 4700 | 4.9686 | 23.3788 | 292.4484 | 50.3509 |
| 4800 | 4.9688 | 23.8756 | 292.9452 | 50.4555 |
| 4900 | 4.9690 | 24.3725 | 293.4421 | 50.5579 |
| 5000 | 4.9692 | 24.8694 | 293.9390 | 50.6583 |
| 5100 | 4.9694 | 25.3664 | 294.4360 | 50.7567 |
| 5200 | 4.9697 | 25.8633 | 294.9329 | 50.8532 |
| 5300 | 4.9701 | 26.3603 | 295.4299 | 50.9479 |
| 5400 | 4.9705 | 26.8574 | 295.9270 | 51.0408 |
| 5500 | 4.9710 | 27.3544 | 296.4240 | 51.1320 |
| 5600 | 4.9716 | 27.8516 | 296.9212 | 51.2216 |
| 5700 | 4.9722 | 28.3487 | 297.4183 | 51.3096 |
| 5800 | 4.9728 | 28.8460 | 297.9156 | 51.3961 |
| 5900 | 4.9736 | 29.3433 | 298.4129 | 51.4811 |
| 6000 | 4.9745 | 29.8407 | 298.9103 | 51.5647 |

## TABLE XIII—THERMODYNAMIC PROPERTIES OF $B_2$ (GAS)

[Molecular weight, 21.64]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | ---------- | 0 | 468.6652 | ---------- | ---------- | -------- | ---------- | ---------- | -------- | ---------- |
| 298.16 | 7.289 | 2.0934 | 470.7586 | 48.652 | 118.8190 | -------- | ---------- | 46.2160 | -------- | ---------- |
| 300 | 7.295 | 2.1068 | 470.7720 | 48.697 | 118.0963 | -------- | ---------- | 45.8995 | -------- | ---------- |
| 400 | 7.645 | 2.8540 | 471.5192 | 50.844 | 88.8842 | -------- | ---------- | 33.0562 | -------- | ---------- |
| 500 | 7.950 | 3.6338 | 472.2990 | 52.584 | 71.3228 | -------- | ---------- | 25.3251 | -------- | ---------- |
| 600 | 8.165 | 4.4398 | 473.1050 | 54.062 | 59.5932 | -------- | ---------- | 20.1558 | -------- | ---------- |
| 700 | 8.330 | 5.2646 | 473.9298 | 55.323 | 51.2012 | -------- | ---------- | 16.4542 | -------- | ---------- |
| 800 | 8.450 | 6.1042 | 474.7694 | 56.444 | 44.8980 | -------- | ---------- | 13.6718 | -------- | ---------- |
| 900 | 8.540 | 6.9537 | 475.6189 | 57.445 | 39.9899 | -------- | ---------- | 11.5032 | -------- | ---------- |
| 1000 | 8.608 | 7.8115 | 476.4767 | 58.348 | 36.0693 | 3526 | 0.01325 | 9.7646 | 1552 | 0.01399 |
| 1100 | 8.665 | 8.6751 | 477.3403 | 59.1711 | 32.8406 | 3209 | 0.01003 | 8.3397 | 1413 | 0.01210 |
| 1200 | 8.704 | 9.5436 | 478.2088 | 59.9267 | 30.1564 | 2944 | .00798 | 7.1501 | 1296 | .01138 |
| 1300 | 8.738 | 10.4157 | 479.0809 | 60.6248 | 27.8838 | 2720 | .00624 | 6.1418 | 1198 | .00999 |
| 1400 | 8.764 | 11.2898 | 479.9560 | 61.2732 | 25.9347 | 2528 | .00467 | 5.2761 | 1113 | .00940 |
| 1500 | 8.784 | 12.1682 | 480.8334 | 61.8756 | 24.2447 | 2359 | .00502 | 4.5247 | 1040 | .00860 |
| 1600 | 8.808 | 13.0475 | 481.7127 | 62.4461 | 22.7663 | 2213 | 0.00404 | 3.8661 | 976 | 0.00788 |
| 1700 | 8.820 | 13.9287 | 482.5939 | 62.9803 | 21.4595 | 2084 | .00342 | 3.2841 | 919 | .00764 |
| 1800 | 8.832 | 14.8113 | 483.4765 | 63.4848 | 20.2983 | 1969 | .00288 | 2.7659 | 869 | .00693 |
| 1900 | 8.842 | 15.6950 | 484.3602 | 63.9626 | 19.2591 | 1866 | .00260 | 2.3016 | 824 | .00650 |
| 2000 | 8.852 | 16.5797 | 485.2449 | 64.4164 | 18.3235 | 1774 | .00184 | 1.8831 | 784 | .00597 |
| 2100 | 8.860 | 17.4653 | 486.1305 | 64.8484 | 17.4769 | 1690 | 0.00172 | 1.5038 | 747 | 0.00565 |
| 2200 | 8.868 | 18.3517 | 487.0169 | 65.2608 | 16.7070 | 1614 | .00136 | 1.1586 | 714 | .00527 |
| 2300 | 8.874 | 19.2388 | 487.9040 | 65.6551 | 16.0039 | 1544 | .00127 | .8429 | 683 | .00522 |
| 2400 | 8.880 | 20.1265 | 488.7917 | 66.0329 | 15.3593 | 1480 | .00120 | .5531 | 655 | .00500 |
| 2500 | 8.884 | 21.0147 | 489.6799 | 66.3955 | 14.7661 | 1421 | .00106 | .2861 | 630 | .00419 |
| 2600 | 8.888 | 21.9033 | 490.5685 | 66.7440 | 14.2185 | 1367 | 0.00080 | 0.0393 | 606 | 0.00416 |
| 2700 | 8.891 | 22.7922 | 491.4574 | 67.0795 | 13.7114 | 1316 | .00090 | −.1896 | 584 | .00423 |
| 2800 | 8.895 | 23.6815 | 492.3467 | 67.4029 | 13.2405 | 1270 | .00067 | −.4024 | 564 | .00392 |
| 2900 | 8.898 | 24.5712 | 493.2364 | 67.7151 | 12.8019 | 1228 | .00063 | −.6008 | 545 | .00383 |
| 3000 | 8.901 | 25.4611 | 494.1263 | 68.0168 | 12.3926 | 1185 | .00074 | −.7863 | 527 | .00370 |
| 3100 | 8.903 | 26.3513 | 495.0165 | 68.3087 | 12.0096 | 1147 | 0.00066 | −0.9600 | 511 | 0.00341 |
| 3200 | 8.906 | 27.2418 | 495.9070 | 68.5914 | 11.6505 | 1111 | .00063 | −1.1231 | 495 | .00340 |
| 3300 | 8.908 | 28.1325 | 496.7977 | 68.8655 | 11.3132 | 1078 | .00054 | −1.2765 | 481 | .00323 |
| 3400 | 8.910 | 29.0234 | 497.6886 | 69.1314 | 10.9956 | 1046 | .00054 | −1.4212 | 466 | .00336 |
| 3500 | 8.912 | 29.9145 | 498.5797 | 69.3898 | 10.6962 | 1016 | .00058 | −1.5577 | 453 | .00327 |
| 3600 | 8.915 | 30.8058 | 499.4710 | 69.6409 | 10.4134 | 988 | 0.00057 | −1.6868 | 441 | 0.00311 |
| 3700 | 8.917 | 31.6974 | 500.3626 | 69.8852 | 10.1458 | 961 | .00061 | −1.8091 | 429 | .00311 |
| 3800 | 8.919 | 32.5892 | 501.2544 | 70.1230 | 9.8923 | 936 | .00050 | −1.9251 | 419 | .00286 |
| 3900 | 8.921 | 33.4812 | 502.1464 | 70.3547 | 9.6518 | 912 | .00060 | −2.0354 | 408 | .00280 |
| 4000 | 8.923 | 34.3734 | 503.0386 | 70.5806 | 9.4232 | 889 | .00057 | −2.1402 | 398 | .00263 |
| 4100 | 8.925 | 35.2658 | 503.9310 | 70.8009 | 9.2058 | 867 | 0.00067 | −2.2401 | 389 | 0.00268 |
| 4200 | 8.927 | 36.1584 | 504.8236 | 71.0160 | 8.9987 | 847 | .00052 | −2.3354 | 380 | .00253 |
| 4300 | 8.930 | 37.0513 | 505.7165 | 71.2261 | 8.8012 | 827 | .00055 | −2.4263 | 371 | .00258 |
| 4400 | 8.932 | 37.9444 | 506.6096 | 71.4314 | 8.6127 | 808 | .00054 | −2.5132 | 363 | .00253 |
| 4500 | 8.935 | 38.8377 | 507.5029 | 71.6322 | 8.4326 | 790 | .00066 | −2.5964 | 355 | .00253 |
| 4600 | 8.937 | 39.7313 | 508.3965 | 71.8286 | 8.2602 | 773 | 0.00063 | −2.6761 | 348 | 0.00236 |
| 4700 | 8.940 | 40.6252 | 509.2904 | 72.0208 | 8.0951 | 756 | .00070 | −2.7525 | 341 | .00226 |
| 4800 | 8.944 | 41.5194 | 510.1846 | 72.2091 | 7.9369 | 740 | .00078 | 2.8258 | 334 | .00224 |
| 4900 | 8.947 | 42.4139 | 511.0791 | 72.3935 | 7.7851 | 724 | .00090 | −2.8962 | 327 | .00220 |
| 5000 | 8.951 | 43.3008 | 511.9740 | 72.5743 | 7.6394 | 710 | .00088 | −2.9638 | 321 | .00216 |
| 5100 | 8.955 | 44.2041 | 512.8693 | 72.7516 | 7.4993 | 695 | 0.00105 | −3.0289 | 315 | 0.00212 |
| 5200 | 8.959 | 45.0998 | 513.7650 | 72.9255 | 7.3646 | 682 | .00102 | −3.0916 | 309 | .00210 |
| 5300 | 8.963 | 45.9959 | 514.6611 | 73.0962 | 7.2349 | 669 | .00101 | −3.1520 | 303 | .00209 |
| 5400 | 8.968 | 46.8925 | 515.5577 | 73.2638 | 7.1100 | 656 | .00118 | −3.2102 | 298 | .00202 |
| 5500 | 8.973 | 47.7895 | 516.4547 | 73.4284 | 6.9896 | 644 | .00110 | −3.2664 | 293 | .00168 |
| 5600 | 8.979 | 48.6871 | 517.3523 | 73.5901 | 6.8735 | 632 | 0.00122 | −3.3206 | 288 | 0.00187 |
| 5700 | 8.985 | 49.5853 | 518.2505 | 73.7491 | 6.7614 | 620 | .00130 | −3.3730 | 283 | .00191 |
| 5800 | 8.991 | 50.4841 | 519.1493 | 73.9054 | 6.6532 | 610 | .00131 | −3.4237 | 278 | .00188 |
| 5900 | 8.998 | 51.3836 | 520.0488 | 74.0592 | 6.5485 | 599 | .00137 | −3.4727 | 273 | .00190 |
| 6000 | 9.005 | 52.2837 | 520.9489 | 74.2105 | 6.4473 | -------- | ---------- | −3.5201 | -------- | ---------- |

## TABLE XIV—THERMODYNAMIC PROPERTIES OF BF (GAS)

[Molecular weight, 29.82]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | $\log K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | ---------- | 0 | 218.1759 | ---------- | ---------- | -------- | ---------- | ---------- | -------- | ---------- |
| 298.16 | 7.0696 | 2.0789 | 220.2548 | 47.9001 | 169.0481 | -------- | ---------- | 67.5887 | -------- | ---------- |
| 300 | 7.0729 | 2.0919 | 220.2678 | 47.9437 | 168.0215 | -------- | ---------- | 67.1385 | -------- | ---------- |
| 400 | 7.3044 | 2.8101 | 220.9860 | 50.0081 | 126.4173 | -------- | ---------- | 48.8690 | -------- | ---------- |
| 500 | 7.5718 | 3.5539 | 221.7298 | 51.6668 | 101.4208 | -------- | ---------- | 37.8738 | -------- | ---------- |
| 600 | 7.8149 | 4.3236 | 222.4995 | 53.0604 | 84.7288 | -------- | ---------- | 30.5239 | -------- | ---------- |
| 700 | 8.0158 | 5.1155 | 223.2914 | 54.2897 | 72.7858 | -------- | ---------- | 25.2615 | -------- | ---------- |
| 800 | 8.1760 | 5.9254 | 224.1013 | 55.3710 | 63.8146 | -------- | ---------- | 21.3064 | -------- | ---------- |
| 900 | 8.3024 | 6.7495 | 224.9255 | 56.3416 | 56.8272 | -------- | ---------- | 18.2243 | -------- | ---------- |
| 1000 | 8.4025 | 7.5850 | 225.7609 | 57.2217 | 51.2304 | 5016 | 0.02420 | 15.7542 | 2207 | 0.01784 |
| 1100 | 8.4822 | 8.4293 | 226.6053 | 58.0264 | 46.6462 | 4565 | 0.01963 | 13.7300 | 2009 | 0.01523 |
| 1200 | 8.5464 | 9.2809 | 227.4568 | 58.7673 | 42.8224 | 4189 | .01589 | 12.0406 | 1844 | .01304 |
| 1300 | 8.5986 | 10.1382 | 228.3142 | 59.4535 | 39.5842 | 3870 | .01341 | 10.6091 | 1704 | .01106 |
| 1400 | 8.6415 | 11.0003 | 229.1762 | 60.0924 | 36.8065 | 3597 | .01100 | 9.3803 | 1584 | .01040 |
| 1500 | 8.6770 | 11.8663 | 230.0422 | 60.6898 | 34.3975 | 3360 | .00900 | 8.3139 | 1480 | .00920 |
| 1600 | 8.7068 | 12.7355 | 230.9115 | 61.2508 | 32.2885 | 3152 | 0.00778 | 7.3797 | 1388 | 0.00883 |
| 1700 | 8.7319 | 13.6075 | 231.7834 | 61.7794 | 30.4266 | 2969 | .00635 | 6.5544 | 1308 | .00793 |
| 1800 | 8.7533 | 14.4818 | 232.6577 | 62.2791 | 28.7708 | 2805 | .00588 | 5.8198 | 1236 | .00747 |
| 1900 | 8.7717 | 15.3580 | 233.5340 | 62.7529 | 27.2886 | 2659 | .00500 | 5.1618 | 1172 | .00690 |
| 2000 | 8.7875 | 16.2360 | 234.4120 | 63.2032 | 25.9541 | 2528 | .00399 | 4.5689 | 1115 | .00615 |
| 2100 | 8.8013 | 17.1155 | 235.2914 | 63.6323 | 24.7463 | 2408 | 0.00376 | 4.0318 | 1062 | 0.00597 |
| 2200 | 8.8133 | 17.9962 | 236.1722 | 64.0420 | 23.6480 | 2300 | .00310 | 3.5431 | 1015 | .00550 |
| 2300 | 8.8239 | 18.8781 | 237.0540 | 64.4340 | 22.6449 | 2201 | .00282 | 3.0963 | 971 | .00542 |
| 2400 | 8.8332 | 19.7610 | 237.9369 | 64.8098 | 21.7250 | 2110 | .00240 | 2.6863 | 931 | .00520 |
| 2500 | 8.8415 | 20.6447 | 238.8206 | 65.1705 | 20.8786 | 2026 | .00227 | 2.3087 | 894 | .00505 |
| 2600 | 8.8489 | 21.5292 | 239.7052 | 65.5175 | 20.0971 | 1949 | 0.00195 | 1.9508 | 860 | 0.00496 |
| 2700 | 8.8555 | 22.4145 | 240.5904 | 65.8516 | 19.3733 | 1877 | .00184 | 1.6363 | 829 | .00453 |
| 2800 | 8.8614 | 23.3003 | 241.4763 | 66.1737 | 18.7011 | 1811 | .00152 | 1.3357 | 801 | .00399 |
| 2900 | 8.8668 | 24.1867 | 242.3626 | 66.4848 | 18.0751 | 1749 | .00130 | 1.0555 | 774 | .00380 |
| 3000 | 8.8716 | 25.0736 | 243.2496 | 66.7855 | 17.4908 | 1691 | .00132 | .7937 | 749 | .00359 |
| 3100 | 8.8760 | 25.9610 | 244.1370 | 67.0764 | 16.9440 | 1637 | 0.00104 | 0.5485 | 725 | 0.00354 |
| 3200 | 8.8800 | 26.8488 | 245.0248 | 67.3583 | 16.4314 | 1586 | .00099 | .3184 | 703 | .00327 |
| 3300 | 8.8837 | 27.7370 | 245.9130 | 67.6316 | 15.9498 | 1538 | .00105 | .1021 | 682 | .00321 |
| 3400 | 8.8870 | 28.6256 | 246.8015 | 67.8969 | 15.4964 | 1493 | .00093 | −.1017 | 662 | .00326 |
| 3500 | 8.8901 | 29.5144 | 247.6904 | 68.1545 | 15.0689 | 1451 | .00084 | −.2941 | 644 | .00301 |
| 3600 | 8.8929 | 30.4036 | 248.5795 | 68.4050 | 14.6650 | 1411 | 0.00065 | −0.4760 | 626 | 0.00301 |
| 3700 | 8.8955 | 31.2930 | 249.4690 | 68.6487 | 14.2830 | 1373 | .00068 | −.6482 | 610 | .00287 |
| 3800 | 8.8979 | 32.1827 | 250.3586 | 68.8860 | 13.9210 | 1337 | .00058 | −.8116 | 593 | .00295 |
| 3900 | 8.9001 | 33.0726 | 251.2485 | 69.1171 | 13.5776 | 1303 | .00055 | −.9666 | 579 | .00275 |
| 4000 | 8.9022 | 33.9627 | 252.1386 | 69.3425 | 13.2513 | 1270 | .00074 | −1.1141 | 565 | .00270 |
| 4100 | 8.9041 | 34.8530 | 253.0290 | 69.5623 | 12.9408 | 1239 | 0.00060 | −1.2546 | 551 | 0.00281 |
| 4200 | 8.9059 | 35.7435 | 253.9195 | 69.7769 | 12.6452 | 1210 | .00050 | −1.3884 | 538 | .00268 |
| 4300 | 8.9075 | 36.6342 | 254.8101 | 69.9865 | 12.3633 | 1182 | .00056 | −1.5162 | 526 | .00255 |
| 4400 | 8.9091 | 37.5250 | 255.7009 | 70.1913 | 12.0941 | 1155 | .00053 | −1.6383 | 514 | .00258 |
| 4500 | 8.9105 | 38.4160 | 256.5920 | 70.3915 | 11.8369 | 1129 | .00057 | −1.7551 | 503 | .00245 |
| 4600 | 8.9119 | 39.3071 | 257.4830 | 70.5874 | 11.5909 | 1105 | 0.00049 | −1.8609 | 492 | 0.00252 |
| 4700 | 8.9132 | 40.1983 | 258.3743 | 70.7790 | 11.3553 | 1082 | .00038 | −1.9741 | 482 | .00238 |
| 4800 | 8.9144 | 41.0897 | 259.2657 | 70.9667 | 11.1295 | 1060 | .00017 | −2.0769 | 472 | .00227 |
| 4900 | 8.9155 | 41.9812 | 260.1571 | 71.1505 | 10.9130 | 1039 | .00020 | −2.1755 | 463 | .00230 |
| 5000 | 8.9165 | 42.8728 | 261.0487 | 71.3306 | 10.7050 | 1018 | .00019 | −2.2704 | 454 | .00218 |
| 5100 | 8.9175 | 43.7645 | 261.9405 | 71.5072 | 10.5052 | 998 | 0.00018 | −2.3616 | 445 | 0.00222 |
| 5200 | 8.9184 | 44.6563 | 262.8322 | 71.6804 | 10.3131 | 979 | .00008 | −2.4494 | 437 | .00205 |
| 5300 | 8.9193 | 45.5483 | 263.7242 | 71.8503 | 10.1283 | 960 | .00022 | −2.5339 | 429 | .00206 |
| 5400 | 8.9202 | 46.4402 | 264.6161 | 72.0170 | 9.9503 | 943 | .00015 | −2.6154 | 421 | .00205 |
| 5500 | 8.9210 | 47.3323 | 265.5082 | 72.1807 | 9.7787 | 926 | .00004 | −2.6940 | 414 | .00197 |
| 5600 | 8.9217 | 48.2244 | 266.4003 | 72.3414 | 9.6133 | 910 | 0.00005 | −2.7699 | 407 | 0.00190 |
| 5700 | 8.9224 | 49.1166 | 267.2926 | 72.4994 | 9.4536 | 894 | −.00004 | −2.8432 | 400 | .00183 |
| 5800 | 8.9231 | 50.0089 | 268.1848 | 72.6546 | 9.2995 | 879 | −.00008 | −2.9140 | 393 | .00179 |
| 5900 | 8.9237 | 50.9012 | 269.0771 | 72.8071 | 9.1506 | 864 | −.00010 | −2.9824 | 387 | .00180 |
| 6000 | 8.9244 | 51.7936 | 269.9696 | 72.9571 | 9.0067 | -------- | ---------- | −3.0487 | -------- | ---------- |

## TABLE XV—THERMODYNAMIC PROPERTIES OF $BF_3$ (GAS)

[Molecular weight, 67.82]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | -------- | 0 | 0 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.18 | 12.0621 | 2.7842 | 2.7842 | 60.6958 | 704.3124 | -------- | -------- | 286.2741 | -------- | -------- |
| 300 | 12.0981 | 2.8066 | 2.8066 | 60.7712 | 700.0206 | -------- | -------- | 284.3981 | -------- | -------- |
| 400 | 13.7643 | 4.1030 | 4.1030 | 64.4894 | 526.0482 | -------- | -------- | 208.3238 | -------- | -------- |
| 500 | 15.0594 | 5.5471 | 5.5471 | 67.7061 | 421.4916 | -------- | -------- | 162.5976 | -------- | -------- |
| 600 | 16.0460 | 7.1046 | 7.1046 | 70.5433 | 351.6741 | -------- | -------- | 132.0708 | -------- | -------- |
| 700 | 16.7919 | 8.7482 | 8.7482 | 73.0755 | 301.7803 | -------- | -------- | 110.2416 | -------- | -------- |
| 800 | 17.3580 | 10.4570 | 10.4570 | 75.3564 | 264.2235 | -------- | -------- | 93.8552 | -------- | -------- |
| 900 | 17.7915 | 12.2154 | 12.2154 | 77.4270 | 235.0185 | -------- | -------- | 81.1010 | -------- | -------- |
| 1000 | 18.1277 | 14.0120 | 14.0120 | 79.3197 | 211.6314 | 20,979 | 0.07908 | 70.8915 | 9168 | 0.02195 |
| 1100 | 18.3922 | 15.8380 | 15.8380 | 81.0598 | 192.4805 | 19,069 | 0.06350 | 62.5341 | 8339 | 0.01823 |
| 1200 | 18.6030 | 17.6878 | 17.6878 | 82.6692 | 176.5095 | 17,513 | .05116 | 55.5667 | 7648 | .01462 |
| 1300 | 18.7731 | 19.5566 | 19.5566 | 84.1650 | 162.9868 | 16,178 | .04179 | 49.6690 | 7063 | .01180 |
| 1400 | 18.9122 | 21.4409 | 21.4409 | 85.5613 | 151.3893 | 15,033 | .03430 | 44.6122 | 6561 | .00970 |
| 1500 | 19.0270 | 23.3378 | 23.3378 | 86.8700 | 141.3330 | 14,039 | .02882 | 40.2285 | 6126 | .00795 |
| 1600 | 19.1228 | 25.3453 | 25.2453 | 88.1010 | 132.5298 | 13,169 | 0.02423 | 36.3918 | 5745 | 0.00699 |
| 1700 | 19.2035 | 27.1616 | 27.1616 | 89.2628 | 124.7591 | 12,400 | .02091 | 33.0057 | 5409 | .00540 |
| 1800 | 19.2720 | 29.0854 | 29.0854 | 90.3623 | 117.8493 | 11,717 | .01746 | 29.9953 | 5110 | .00443 |
| 1900 | 19.3306 | 31.0155 | 31.0155 | 91.4059 | 111.6650 | 11,105 | .01520 | 27.3014 | 4842 | .00400 |
| 2000 | 19.3813 | 32.9511 | 32.9511 | 92.3967 | 106.0973 | 10,554 | .01309 | 24.8764 | 4601 | .00335 |
| 2100 | 19.4252 | 34.8915 | 34.8915 | 93.3454 | 101.0585 | 10,055 | 0.01135 | 22.6821 | 4383 | 0.00253 |
| 2200 | 19.4635 | 36.8359 | 36.8359 | 94.2499 | 96.4767 | 9,601 | .00995 | 20.6870 | 4184 | .00267 |
| 2300 | 19.4971 | 38.7839 | 38.7839 | 95.1159 | 92.2924 | 8,186 | .00890 | 18.8652 | 4003 | .00228 |
| 2400 | 19.5268 | 40.7351 | 40.7351 | 95.9463 | 88.4560 | 8,806 | .00780 | 17.1950 | 3837 | .00190 |
| 2500 | 19.5532 | 42.6891 | 42.6891 | 96.7440 | 84.9258 | 8,456 | .00689 | 15.6583 | 3684 | .00168 |
| 2600 | 19.5766 | 44.6456 | 44.6456 | 97.5113 | 81.6666 | 8,133 | 0.00608 | 14.2397 | 3543 | 0.00148 |
| 2700 | 19.5976 | 46.6043 | 46.6043 | 98.2505 | 78.0483 | 7,838 | .00560 | 12.9260 | 3412 | .00133 |
| 2800 | 19.6165 | 48.5650 | 48.5650 | 98.9636 | 75.8452 | 7,555 | .00503 | 11.7061 | 3291 | .00107 |
| 2900 | 19.6332 | 50.5275 | 50.5275 | 99.6522 | 73.2350 | 7,296 | .00450 | 10.5702 | 3178 | .00087 |
| 3000 | 19.6486 | 52.4916 | 52.4916 | 100.3181 | 70.7985 | 7,054 | .00412 | 9.5100 | 3072 | .00083 |
| 3100 | 19.6626 | 54.4572 | 54.4572 | 100.9626 | 68.5189 | 6,827 | 0.00396 | 8.5182 | 2973 | 0.00094 |
| 3200 | 19.6753 | 56.4241 | 56.4241 | 101.5871 | 66.3815 | 6,615 | .00346 | 7.5882 | 2880 | .00087 |
| 3300 | 19.6867 | 58.3922 | 58.3922 | 102.1927 | 64.3735 | 6,416 | .00304 | 6.7146 | 2793 | .00083 |
| 3400 | 19.6972 | 60.3614 | 60.3614 | 102.7805 | 62.4834 | 6,228 | .00287 | 5.8923 | 2711 | .00063 |
| 3500 | 19.7069 | 62.3316 | 62.3316 | 103.3516 | 60.7011 | 6,051 | .00257 | 5.1169 | 2634 | .00063 |
| 3600 | 19.7158 | 64.3027 | 64.3027 | 103.9069 | 59.0177 | 5,884 | 0.00233 | 4.3846 | 2561 | 0.00054 |
| 3700 | 19.7240 | 66.2747 | 66.2747 | 104.4472 | 57.4251 | 5,725 | .00232 | 3.6919 | 2492 | .00051 |
| 3800 | 19.7316 | 68.2475 | 68.2475 | 104.9733 | 55.9162 | 5,575 | .00211 | 3.0356 | 2427 | .00039 |
| 3900 | 19.7386 | 70.2210 | 70.2210 | 105.4860 | 54.4846 | 5,433 | .00185 | 2.4129 | 2365 | .00035 |
| 4000 | 19.7451 | 72.1952 | 72.1952 | 105.9858 | 53.1245 | 5,298 | .00171 | 1.8213 | 2306 | .00026 |
| 4100 | 19.7511 | 74.1700 | 74.1700 | 106.4734 | 51.8306 | 5,169 | 0.00169 | 1.2586 | 2250 | 0.00029 |
| 4200 | 19.7567 | 76.1454 | 76.1454 | 106.9494 | 50.5982 | 5,046 | .00161 | .7226 | 2196 | .00030 |
| 4300 | 19.7619 | 78.1213 | 78.1213 | 107.4144 | 49.4281 | 4,929 | .00157 | .2116 | 2145 | .00030 |
| 4400 | 19.7668 | 80.0977 | 80.0977 | 107.8688 | 48.3013 | 4,817 | .00146 | −.2762 | 2097 | .00020 |
| 4500 | 19.7714 | 82.0746 | 82.0746 | 108.3130 | 47.2294 | 4,711 | .00127 | −.7424 | 2050 | .00025 |
| 4600 | 19.7737 | 84.0519 | 84.0519 | 108.7476 | 46.2040 | 4,609 | .00116 | −1.1883 | 2006 | 0.00019 |
| 4700 | 19.7777 | 86.0295 | 86.0295 | 109.1729 | 45.2222 | 4,512 | .00100 | −1.6153 | 1963 | .00014 |
| 4800 | 19.7814 | 88.0074 | 88.0074 | 109.5893 | 44.2812 | 4,418 | .00097 | −2.0244 | 1922 | .00026 |
| 4900 | 19.7849 | 89.9857 | 89.9857 | 109.9972 | 43.3786 | 4,328 | .00090 | −2.4169 | 1883 | .00020 |
| 5000 | 19.7882 | 91.9644 | 91.9644 | 110.3970 | 42.5121 | 4,242 | .00084 | −2.7937 | 1845 | .00024 |
| 5100 | 19.7913 | 93.9434 | 93.9434 | 110.7889 | 41.6795 | 4,159 | 0.00079 | −3.1557 | 1809 | 0.00022 |
| 5200 | 19.7942 | 95.9226 | 95.9226 | 111.1732 | 40.8789 | 4,079 | .00078 | −3.5038 | 1775 | .00009 |
| 5300 | 19.7969 | 97.9022 | 97.9022 | 111.5503 | 40.1085 | 4,002 | .00079 | −3.8388 | 1741 | .00019 |
| 5400 | 19.7995 | 99.8820 | 99.8820 | 111.9204 | 39.3666 | 3,929 | .00064 | −4.1614 | 1708 | .00025 |
| 5500 | 19.8020 | 101.8621 | 101.8621 | 112.2837 | 38.6516 | 3,857 | .00065 | −4.4722 | 1678 | .00016 |
| 5600 | 19.8044 | 103.8424 | 103.8424 | 112.6405 | 37.9622 | 3,789 | 0.00056 | −4.7720 | 1648 | 0.00008 |
| 5700 | 19.8067 | 105.8230 | 105.8230 | 112.9910 | 37.2969 | 3,722 | .00058 | −5.0612 | 1619 | .00016 |
| 5800 | 19.8089 | 107.8037 | 107.8037 | 113.3355 | 36.6546 | 3,659 | .00043 | −5.3405 | 1591 | .00014 |
| 5900 | 19.8110 | 109.7847 | 109.7847 | 113.6742 | 36.0340 | 3,597 | .00040 | −5.6103 | 1564 | .00013 |
| 6000 | 19.8131 | 111.7659 | 111.7659 | 114.0072 | 35.4341 | -------- | -------- | −5.8711 | -------- | -------- |

## TABLE XVI—THERMODYNAMIC PROPERTIES OF BH (GAS)

[Molecular weight, 11.828]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ $a$ | $b$ | $\log K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ $c$ | $d$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -------- | 0 | 279.8258 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.16 | 6.9593 | 2.0739 | 281.8997 | 41.0362 | 127.4086 | -------- | -------- | 50.3050 | -------- | -------- |
| 300 | 6.9596 | 2.0867 | 281.9125 | 41.0790 | 126.6364 | -------- | -------- | 49.9656 | -------- | -------- |
| 400 | 6.9931 | 2.7839 | 282.6097 | 43.0847 | 95.3504 | -------- | -------- | 36.1918 | -------- | -------- |
| 500 | 7.0796 | 3.4871 | 283.3129 | 44.6534 | 76.5727 | -------- | -------- | 27.8950 | -------- | -------- |
| 600 | 7.2130 | 4.2014 | 284.0272 | 45.9554 | 64.0449 | -------- | -------- | 22.3429 | -------- | -------- |
| 700 | 7.3713 | 4.9305 | 284.7563 | 47.0790 | 55.0858 | -------- | -------- | 18.3628 | -------- | -------- |
| 800 | 7.5344 | 5.6758 | 285.5016 | 48.0740 | 48.3563 | -------- | -------- | 15.3677 | -------- | -------- |
| 900 | 7.6897 | 6.4371 | 286.2629 | 48.9705 | 43.1133 | -------- | -------- | 13.0308 | -------- | -------- |
| 1000 | 7.8309 | 7.2133 | 287.0391 | 49.7881 | 38.9114 | 3754 | 0.03127 | 11.1558 | 1667 | 0.02285 |
| 1100 | 7.9561 | 8.0026 | 287.8284 | 50.5404 | 35.4674 | 3417 | 0.02740 | 9.6175 | 1519 | 0.01927 |
| 1200 | 8.0656 | 8.8037 | 288.6295 | 51.2378 | 32.5925 | 3136 | .02419 | 8.3324 | 1395 | .01702 |
| 1300 | 8.1607 | 9.6150 | 289.4408 | 51.8867 | 30.1560 | 2899 | .02089 | 7.2423 | 1290 | .01507 |
| 1400 | 8.2431 | 10.4352 | 290.2610 | 52.4945 | 28.0644 | 2696 | .01807 | 6.3058 | 1200 | .01340 |
| 1500 | 8.3144 | 11.2631 | 291.0889 | 53.0656 | 26.2490 | 2520 | .01550 | 5.4924 | 1122 | .01195 |
| 1600 | 8.3764 | 12.0976 | 291.9234 | 53.6042 | 24.6585 | 2366 | 0.01344 | 4.7792 | 1054 | 0.01060 |
| 1700 | 8.4302 | 12.9380 | 292.7638 | 54.1136 | 23.2533 | 2229 | .01217 | 4.1486 | 993 | .00983 |
| 1800 | 8.4772 | 13.7833 | 293.6091 | 54.5968 | 22.0028 | 2108 | .01033 | 3.5871 | 939 | .00919 |
| 1900 | 8.5184 | 14.6331 | 294.4589 | 55.0562 | 20.8830 | 2000 | .00900 | 3.0837 | 891 | .00840 |
| 2000 | 8.5546 | 15.4868 | 295.3126 | 55.4941 | 19.8740 | 1902 | .00789 | 2.6298 | 848 | .00749 |
| 2100 | 8.5866 | 16.3438 | 296.1696 | 55.9123 | 18.9604 | 1813 | 0.00721 | 2.2185 | 809 | 0.00687 |
| 2200 | 8.6150 | 17.2039 | 297.0297 | 56.3124 | 18.1291 | 1733 | .00612 | 1.8439 | 773 | .00651 |
| 2300 | 8.6401 | 18.0667 | 297.8925 | 56.6959 | 17.3695 | 1659 | .00555 | 1.5013 | 740 | .00627 |
| 2400 | 8.6626 | 18.9318 | 298.7576 | 57.0641 | 16.6727 | 1591 | .00510 | 1.1867 | 710 | .00580 |
| 2500 | 8.6828 | 19.7991 | 299.6249 | 57.4181 | 16.0312 | 1529 | .00442 | .8969 | 682 | .00569 |
| 2600 | 8.7009 | 20.6683 | 300.4941 | 57.7590 | 15.4387 | 1471 | 0.00409 | 0.6289 | 657 | 0.00527 |
| 2700 | 8.7172 | 21.5392 | 301.3650 | 58.0877 | 14.8898 | 1418 | .00357 | .3803 | 633 | .00503 |
| 2800 | 8.7320 | 22.4116 | 302.2374 | 58.4050 | 14.3798 | 1368 | .00338 | .1492 | 611 | .00481 |
| 2900 | 8.7453 | 23.2855 | 303.1113 | 58.7116 | 13.9047 | 1322 | .00293 | —.0663 | 590 | .00473 |
| 3000 | 8.7575 | 24.1606 | 303.9864 | 59.0083 | 13.4611 | 1279 | .00262 | —.2677 | 571 | .00451 |
| 3100 | 8.7686 | 25.0369 | 304.8627 | 59.2956 | 13.0459 | 1238 | 0.00252 | —0.4564 | 554 | 0.00408 |
| 3200 | 8.7788 | 25.9143 | 305.7401 | 59.5742 | 12.6565 | 1200 | .00236 | —.6336 | 537 | .00397 |
| 3300 | 8.7881 | 26.7926 | 306.6184 | 59.8445 | 12.2905 | 1164 | .00225 | —.8003 | 521 | .00386 |
| 3400 | 8.7966 | 27.6719 | 307.4977 | 60.1070 | 11.9459 | 1130 | .00204 | —.9574 | 506 | .00373 |
| 3500 | 8.8045 | 28.5519 | 308.3777 | 60.3621 | 11.6210 | 1099 | .00182 | —1.1057 | 492 | .00363 |
| 3600 | 8.8117 | 29.4327 | 309.2585 | 60.6102 | 11.3139 | 1068 | 0.00185 | —1.2460 | 479 | 0.00344 |
| 3700 | 8.8184 | 30.3143 | 310.1401 | 60.8517 | 11.0234 | 1040 | .00162 | —1.3789 | 466 | .00347 |
| 3800 | 8.8246 | 31.1964 | 311.0222 | 61.0870 | 10.7481 | 1013 | .00156 | —1.5050 | 454 | .00339 |
| 3900 | 8.8304 | 32.0792 | 311.9050 | 61.3163 | 10.4868 | 988 | .00130 | —1.6248 | 443 | .00315 |
| 4000 | 8.8357 | 32.9625 | 312.7883 | 61.5399 | 10.2385 | 964 | .00118 | —1.7387 | 432 | .00313 |
| 4100 | 8.8407 | 33.8463 | 313.6721 | 61.7581 | 10.0022 | 940 | 0.00119 | —1.8472 | 422 | 0.00302 |
| 4200 | 8.8453 | 34.7306 | 314.5564 | 61.9712 | 9.7772 | 918 | .00111 | —1.9507 | 412 | .00299 |
| 4300 | 8.8497 | 35.6153 | 315.4411 | 62.1794 | 9.5626 | 897 | .00114 | —2.0495 | 403 | .00291 |
| 4400 | 8.8537 | 36.5005 | 316.3263 | 62.3829 | 9.3576 | 877 | .00091 | —2.1440 | 394 | .00274 |
| 4500 | 8.8575 | 37.3861 | 317.2119 | 62.5819 | 9.1618 | 858 | .00088 | —2.2343 | 386 | .00269 |
| 4600 | 8.8611 | 38.2720 | 318.0978 | 62.7766 | 8.9744 | 840 | 0.00078 | —2.3209 | 378 | 0.00257 |
| 4700 | 8.8644 | 39.1583 | 318.9841 | 62.9672 | 8.7949 | 822 | .00075 | —2.4039 | 370 | .00252 |
| 4800 | 8.8676 | 40.0449 | 319.8707 | 63.1539 | 8.6229 | 805 | .00072 | —2.4835 | 363 | .00242 |
| 4900 | 8.8705 | 40.9318 | 320.7576 | 63.3368 | 8.4579 | 789 | .00060 | —2.5600 | 356 | .00230 |
| 5000 | 8.8733 | 41.8190 | 321.6448 | 63.5160 | 8.2995 | 774 | .00054 | —2.6335 | 349 | .00227 |
| 5100 | 8.8759 | 42.7064 | 322.5322 | 63.6918 | 8.1472 | 758 | 0.00063 | —2.7042 | 342 | 0.00233 |
| 5200 | 8.8784 | 43.5941 | 323.4199 | 63.8641 | 8.0008 | 744 | .00052 | —2.7723 | 336 | .00220 |
| 5300 | 8.8807 | 44.4821 | 324.3079 | 64.0333 | 7.8599 | 730 | .00052 | —2.8379 | 330 | .00209 |
| 5400 | 8.8830 | 45.3703 | 325.1961 | 64.1993 | 7.7242 | 717 | .00044 | —2.9011 | 325 | .00201 |
| 5500 | 8.8850 | 46.2587 | 326.0845 | 64.3623 | 7.5934 | 704 | .00039 | —2.9622 | 319 | .00194 |
| 5600 | 8.8870 | 47.1473 | 326.9731 | 64.5224 | 7.4673 | 692 | 0.00040 | —3.0211 | 313 | 0.00199 |
| 5700 | 8.8889 | 48.0361 | 327.8619 | 64.6797 | 7.3455 | 680 | .00026 | —3.0780 | 308 | .00200 |
| 5800 | 8.8907 | 48.9251 | 328.7509 | 64.8343 | 7.2280 | 668 | .00028 | —3.1331 | 303 | .00184 |
| 5900 | 8.8924 | 49.8142 | 329.6400 | 64.9863 | 7.1145 | 657 | .00030 | —3.1863 | 298 | .00183 |
| 6000 | 8.8941 | 50.7035 | 330.5293 | 65.1358 | 7.0047 | -------- | -------- | —3.2378 | -------- | -------- |

## TABLE XVII—THERMODYNAMIC PROPERTIES OF BO (GAS)

[Molecular weight, 26.82]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ-H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | $\log K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | ---------- | 0 | 168.1616 | ---------- | ---------- | | | ---------- | | |
| 298.16 | 6.976 | 2.0731 | 170.2347 | 48.605 | 272.6696 | -------- | ---------- | 112.6245 | -------- | ---------- |
| 300 | 6.977 | 2.0859 | 170.2475 | 48.647 | 271.0072 | -------- | ---------- | 111.8980 | -------- | ---------- |
| 400 | 7.062 | 2.7872 | 170.9488 | 50.664 | 203.6499 | -------- | ---------- | 82.4477 | -------- | ---------- |
| 500 | 7.230 | 3.5018 | 171.6634 | 52.259 | 163.2146 | -------- | ---------- | 64.7442 | -------- | ---------- |
| 600 | 7.427 | 4.2347 | 172.3963 | 53.594 | 136.2359 | -------- | ---------- | 52.9207 | -------- | ---------- |
| 700 | 7.635 | 4.9880 | 173.1496 | 54.755 | 116.9540 | -------- | ---------- | 44.4620 | -------- | ---------- |
| 800 | 7.810 | 5.7600 | 173.9216 | 55.785 | 102.4775 | -------- | ---------- | 38.1086 | -------- | ---------- |
| 900 | 7.970 | 6.5490 | 174.7106 | 56.714 | 91.2079 | -------- | ---------- | 33.1604 | -------- | ---------- |
| 1000 | 8.109 | 7.3530 | 175.5146 | 57.563 | 82.1842 | 8094 | 0.03092 | 29.1974 | 3547 | 0.02195 |
| 1100 | 8.225 | 8.1697 | 176.3313 | 58.3413 | 74.7951 | 7363 | 0.02647 | 25.9509 | 3229 | 0.01747 |
| 1200 | 8.325 | 8.9972 | 177.1588 | 59.0618 | 68.6328 | 6754 | .02252 | 23.2426 | 2963 | .01467 |
| 1300 | 8.411 | 9.8340 | 177.9956 | 59.7310 | 63.4149 | 6239 | .01907 | 20.9487 | 2737 | .01310 |
| 1400 | 8.485 | 10.6788 | 178.8404 | 60.3570 | 58.9394 | 5797 | .01653 | 18.9806 | 2544 | .01120 |
| 1500 | 8.5485 | 11.5305 | 179.6921 | 60.9446 | 55.0582 | 5414 | .01425 | 17.2734 | 2376 | .01010 |
| 1600 | 8.6025 | 12.3881 | 180.5497 | 61.4980 | 51.6602 | 5079 | 0.01195 | 15.7783 | 2229 | 0.00912 |
| 1700 | 8.6483 | 13.2506 | 181.4122 | 62.0209 | 48.6606 | 4788 | .01048 | 14.4580 | 2099 | .00839 |
| 1800 | 8.6883 | 14.1174 | 182.2790 | 62.5164 | 45.9929 | 4520 | .00865 | 13.2835 | 1984 | .00749 |
| 1900 | 8.7235 | 14.9886 | 183.1496 | 62.9871 | 43.6051 | 4284 | .00790 | 12.2318 | 1880 | .00720 |
| 2000 | 8.7550 | 15.8620 | 184.0236 | 63.4354 | 41.4552 | 4071 | .00733 | 11.2846 | 1787 | .00665 |
| 2100 | 8.7835 | 16.7389 | 184.9005 | 63.8632 | 39.5093 | 3879 | 0.00632 | 10.4270 | 1703 | 0.00611 |
| 2200 | 8.8095 | 17.6185 | 185.7801 | 64.2724 | 37.7398 | 3704 | .00587 | 9.6468 | 1627 | .00551 |
| 2300 | 8.8333 | 18.5007 | 186.6623 | 64.6645 | 36.1235 | 3545 | .00492 | 8.9339 | 1556 | .00547 |
| 2400 | 8.8549 | 19.3851 | 187.5467 | 65.0409 | 34.6415 | 3398 | .00460 | 8.2801 | 1493 | .00450 |
| 2500 | 8.8749 | 20.2716 | 188.4332 | 65.4028 | 33.2777 | 3264 | .00382 | 7.6781 | 1434 | .00456 |
| 2600 | 8.8934 | 21.1600 | 189.3216 | 65.7513 | 32.0185 | 3140 | 0.00324 | 7.1220 | 1379 | 0.00436 |
| 2700 | 8.9106 | 22.0502 | 190.2118 | 66.0872 | 30.8523 | 3024 | .00320 | 6.6069 | 1329 | .00406 |
| 2800 | 8.9268 | 22.9421 | 191.1037 | 66.4116 | 29.7691 | 2918 | .00249 | 6.1282 | 1282 | .00393 |
| 2900 | 8.9421 | 23.8355 | 191.9971 | 66.7251 | 28.7604 | 2818 | .00217 | 5.6822 | 1238 | .00383 |
| 3000 | 8.9565 | 24.7304 | 192.8920 | 67.0285 | 27.8189 | 2725 | .00197 | 5.2657 | 1197 | .00367 |
| 3100 | 8.9702 | 25.6268 | 193.7884 | 67.3224 | 26.9379 | 2638 | 0.00162 | 4.8759 | 1159 | 0.00351 |
| 3200 | 8.9833 | 26.5244 | 194.6860 | 67.6074 | 26.1119 | 2557 | .00115 | 4.5102 | 1124 | .00319 |
| 3300 | 8.9959 | 27.4234 | 195.5850 | 67.8840 | 25.3359 | 2480 | .00109 | 4.1664 | 1090 | .00311 |
| 3400 | 9.0081 | 28.3236 | 196.4852 | 68.1527 | 24.6054 | 2408 | .00070 | 3.8427 | 1058 | .00311 |
| 3500 | 9.0200 | 29.2250 | 197.3866 | 68.4140 | 23.9167 | 2340 | .00060 | 3.5373 | 1028 | .00304 |
| 3600 | 9.0316 | 30.1276 | 198.2892 | 68.6683 | 23.2661 | 2275 | 0.00054 | 3.2487 | 1000 | 0.00298 |
| 3700 | 9.0430 | 31.0313 | 199.1929 | 68.9159 | 22.6507 | 2214 | .00037 | 2.9755 | 973 | .00285 |
| 3800 | 9.0543 | 31.9362 | 200.0978 | 69.1572 | 22.0677 | 2157 | .00012 | 2.7166 | 948 | .00272 |
| 3900 | 9.0654 | 32.8422 | 201.0038 | 69.3925 | 21.5145 | 2102 | .00000 | 2.4708 | 924 | .00270 |
| 4000 | 9.0763 | 33.7492 | 201.9108 | 69.6222 | 20.9890 | 2050 | −.00020 | 2.2371 | 901 | .00264 |
| 4100 | 9.0870 | 34.6574 | 202.8190 | 69.8464 | 20.4892 | 2000 | −0.00009 | 2.0147 | 879 | 0.00261 |
| 4200 | 9.0976 | 35.5666 | 203.7282 | 70.0655 | 20.0131 | 1953 | −.00029 | 1.8028 | 859 | .00243 |
| 4300 | 9.1080 | 36.4769 | 204.6385 | 70.2797 | 19.5592 | 1908 | −.00044 | 1.6006 | 839 | .00242 |
| 4400 | 9.1183 | 37.3882 | 205.5498 | 70.4892 | 19.1260 | 1865 | −.00044 | 1.4075 | 820 | .00238 |
| 4500 | 9.1284 | 38.3006 | 206.4622 | 70.6943 | 18.7120 | 1824 | −.00062 | 1.2229 | 802 | .00235 |
| 4600 | 9.1384 | 39.2139 | 207.3755 | 70.8950 | 18.3161 | 1785 | −0.00069 | 1.0462 | 785 | 0.00238 |
| 4700 | 9.1482 | 40.1282 | 208.2898 | 71.0916 | 17.9370 | 1747 | −.00076 | .8768 | 768 | .00230 |
| 4800 | 9.1579 | 41.0325 | 209.2051 | 71.2843 | 17.5738 | 1710 | −.00058 | .7145 | 753 | .00213 |
| 4900 | 9.1675 | 41.9598 | 210.1214 | 71.4733 | 17.2254 | 1676 | −.00070 | .5587 | 738 | .00210 |
| 5000 | 9.1769 | 42.8770 | 211.0386 | 71.6586 | 16.8909 | 1642 | −.00066 | .4090 | 722 | .00223 |
| 5100 | 9.1862 | 43.7952 | 211.9568 | 71.8404 | 16.5696 | 1610 | −0.00072 | 0.2652 | 709 | 0.00215 |
| 5200 | 9.1954 | 44.7143 | 212.8759 | 72.0189 | 16.2607 | 1580 | −.00091 | .1267 | 695 | .00217 |
| 5300 | 9.2045 | 45.6343 | 213.7959 | 72.1941 | 15.9635 | 1550 | −.00084 | −.0066 | 682 | .00210 |
| 5400 | 9.2135 | 46.5552 | 214.7168 | 72.3662 | 15.6773 | 1521 | −.00085 | −.1350 | 669 | .00216 |
| 5500 | 9.2224 | 47.4770 | 215.6386 | 72.5354 | 15.4016 | 1494 | −.00099 | −.2588 | 657 | .00218 |
| 5600 | 9.2312 | 48.3996 | 216.5612 | 72.7016 | 15.1358 | 1467 | −0.00077 | −0.3783 | 645 | 0.00214 |
| 5700 | 9.2399 | 49.3232 | 217.4848 | 72.8651 | 14.8792 | 1441 | −.00085 | −.4936 | 634 | .00219 |
| 5800 | 9.2485 | 50.2476 | 218.4092 | 73.0259 | 14.6316 | 1416 | −.00080 | −.6051 | 623 | .00211 |
| 5900 | 9.2570 | 51.1729 | 219.3345 | 73.1840 | 14.3924 | 1393 | −.00097 | −.7128 | 612 | .00220 |
| 6000 | 9.2654 | 52.0990 | 220.2606 | 73.3397 | 14.1612 | -------- | ---------- | −.8170 | -------- | ---------- |

## TABLE XVIII—THERMODYNAMIC PROPERTIES OF $B_2O_3$ (GAS)

[Molecular weight, 69.64]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | -------- | 0 | 126.0689 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.16 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 300 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 400 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 500 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 600 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 700 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 800 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 900 | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 1000 | 23.360 | 16.5945 | 142.6834 | 82.1636 | 301.8037 | 29,998 | 0.10329 | 101.1271 | 13,090 | 0.01700 |
| 1100 | 23.754 | 18.9502 | 145.0391 | 84.4085 | 274.4295 | 27,295 | 0.08117 | 89.2101 | 11,905 | 0.01197 |
| 1200 | 24.064 | 21.3411 | 147.4300 | 86.4886 | 251.6025 | 25,041 | .06409 | 79.2773 | 10,917 | .00821 |
| 1300 | 24.311 | 23.7599 | 149.8488 | 88.4246 | 232.2761 | 23,131 | .05176 | 70.8714 | 10,081 | .00499 |
| 1400 | 24.510 | 26.2009 | 152.2898 | 90.2335 | 215.7022 | 21,492 | .04230 | 63.6657 | 9,363 | .00340 |
| 1500 | 24.672 | 28.6600 | 154.7489 | 91.9300 | 201.3319 | 20,071 | .03442 | 57.4203 | 8,741 | .00178 |
| 1600 | 24.806 | 31.1339 | 157.2228 | 93.5266 | 188.7531 | 18,825 | 0.02917 | 51.9554 | 8,196 | 0.00092 |
| 1700 | 24.916 | 33.6199 | 159.7088 | 95.0337 | 177.6504 | 17,726 | .02422 | 47.1333 | 7,715 | .00009 |
| 1800 | 25.010 | 36.1162 | 162.2051 | 96.4605 | 167.7784 | 16,748 | .02046 | 42.8471 | 7,287 | −.00026 |
| 1900 | 25.090 | 38.6212 | 164.7101 | 97.8148 | 158.9432 | 15,872 | .01760 | 39.0121 | 6,904 | −.00070 |
| 2000 | 25.159 | 41.1337 | 167.2226 | 99.1036 | 150.9896 | 15,083 | .01532 | 35.5606 | 6,560 | −.00131 |
| 2100 | 25.221 | 43.6527 | 169.7416 | 100.3326 | 143.7919 | 14,368 | 0.01369 | 32.4383 | 6,248 | −0.00160 |
| 2200 | 25.277 | 46.1776 | 172.2665 | 101.5071 | 137.2473 | 13,718 | .01235 | 29.5999 | 5,965 | −.00198 |
| 2300 | 25.329 | 48.7079 | 174.7968 | 102.6319 | 131.2706 | 13,127 | .00992 | 27.0084 | 5,705 | −.00178 |
| 2400 | 25.374 | 51.2430 | 177.3319 | 103.7108 | 125.7911 | 12,587 | .00710 | 24.6331 | 5,468 | −.00210 |
| 2500 | 25.408 | 53.7821 | 179.8710 | 104.7478 | 120.7492 | 12,087 | .00565 | 22.4480 | 5,249 | −.00195 |
| 2600 | 25.439 | 56.3245 | 182.4134 | 105.7445 | 116.0947 | 11,626 | 0.00418 | 20.4311 | 5,047 | −0.00196 |
| 2700 | 25.466 | 58.8697 | 184.9586 | 106.7050 | 111.7846 | 11,197 | .00367 | 18.5638 | 4,861 | −.00227 |
| 2800 | 25.491 | 61.4176 | 187.5065 | 107.6316 | 107.7820 | 10,802 | .00177 | 16.8300 | 4,687 | −.00221 |
| 2900 | 25.514 | 63.9678 | 190.0567 | 108.5266 | 104.0554 | 10,432 | .00097 | 15.2160 | 4,525 | −.00203 |
| 3000 | 25.534 | 66.5202 | 192.6091 | 109.3919 | 100.5771 | 10,087 | .00003 | 13.7097 | 4,374 | −.00207 |
| 3100 | 25.552 | 69.0745 | 195.1634 | 110.2294 | 97.3232 | 9,764 | −0.00065 | 12.3008 | 4,233 | −0.00201 |
| 3200 | 25.570 | 71.6306 | 197.7195 | 111.0409 | 94.2726 | 9,463 | −.00197 | 10.9800 | 4,100 | −.00182 |
| 3300 | 25.585 | 74.1884 | 200.2773 | 111.8280 | 91.4070 | 9,178 | −.00261 | 9.7394 | 3,976 | −.00191 |
| 3400 | 25.599 | 76.7476 | 202.8365 | 112.5920 | 88.7102 | 8,910 | −.00301 | 8.5719 | 3,858 | −.00159 |
| 3500 | 25.613 | 79.3082 | 205.3971 | 113.3342 | 86.1675 | 8,659 | −.00418 | 7.4712 | 3,748 | −.00161 |
| 3600 | 25.624 | 81.8700 | 207.9589 | 114.0560 | 83.7664 | 8,420 | −0.00447 | 6.4317 | 3,644 | −0.00166 |
| 3700 | 25.635 | 84.4330 | 210.5219 | 114.7582 | 81.4952 | 8,195 | −.00528 | 5.4485 | 3,545 | −.00159 |
| 3800 | 25.645 | 86.9970 | 213.0859 | 115.4419 | 79.3439 | 7,980 | −.00535 | 4.5172 | 3,452 | −.00153 |
| 3900 | 25.655 | 89.5620 | 215.6509 | 116.1082 | 77.3031 | 7,779 | −.00635 | 3.6336 | 3,362 | −.00130 |
| 4000 | 25.663 | 92.1279 | 218.2168 | 116.7578 | 75.3647 | 7,585 | −.00640 | 2.7944 | 3,278 | −.00121 |
| 4100 | 25.671 | 94.6946 | 220.7835 | 117.3916 | 73.5211 | 7,401 | −0.00664 | 1.9961 | 3,198 | −0.00123 |
| 4200 | 25.679 | 97.2621 | 223.3510 | 118.0103 | 71.7656 | 7,226 | −.00696 | 1.2359 | 3,122 | −.00125 |
| 4300 | 25.687 | 99.8304 | 225.9193 | 118.6147 | 70.0921 | 7,060 | −.00755 | .5111 | 3,049 | −.00115 |
| 4400 | 25.693 | 102.3994 | 228.4883 | 119.2053 | 68.4951 | 6,900 | −.00753 | −.1807 | 2,979 | −.00090 |
| 4500 | 25.699 | 104.9690 | 231.0579 | 119.7827 | 66.9693 | 6,748 | −.00776 | −.8418 | 2,912 | −.00084 |
| 4600 | 25.705 | 107.5392 | 233.6281 | 120.3476 | 65.5101 | 6,602 | −0.00808 | −1.4740 | 2,849 | −0.00087 |
| 4700 | 25.710 | 110.1099 | 236.1988 | 120.9005 | 64.1135 | 6,461 | −.00784 | −2.0793 | 2,788 | −.00073 |
| 4800 | 25.716 | 112.6812 | 238.7701 | 121.4418 | 62.7753 | 6,328 | −.00823 | −2.6594 | 2,730 | −.00074 |
| 4900 | 25.720 | 115.2530 | 241.3419 | 121.9721 | 61.4921 | 6,198 | −.00800 | −3.2158 | 2,673 | −.00050 |
| 5000 | 25.725 | 117.8253 | 243.9142 | 122.4918 | 60.2605 | 6,075 | −.00818 | −3.7499 | 2,619 | −.00043 |
| 5100 | 25.729 | 120.3980 | 246.4869 | 123.0013 | 59.0775 | 5,956 | −0.00828 | −4.2620 | 2,568 | −0.00045 |
| 5200 | 25.733 | 122.9711 | 249.0600 | 123.5009 | 57.9404 | 5,842 | −.00836 | −4.7564 | 2,518 | −.00029 |
| 5300 | 25.737 | 125.5446 | 251.6335 | 123.9911 | 56.8465 | 5,731 | −.00820 | −5.2312 | 2,470 | −.00021 |
| 5400 | 25.741 | 128.1185 | 254.2074 | 124.4722 | 55.7934 | 5,625 | −.00823 | −5.6884 | 2,424 | −.00013 |
| 5500 | 25.745 | 130.6928 | 256.7817 | 124.9446 | 54.7789 | 5,524 | −.00843 | −6.1290 | 2,379 | −.00002 |
| 5600 | 25.748 | 133.2674 | 259.3563 | 125.4085 | 53.8009 | 5,428 | −0.00800 | −6.5538 | 2,337 | −0.00010 |
| 5700 | 25.752 | 135.8424 | 261.9313 | 125.8643 | 52.8575 | 5,327 | −.00785 | −6.9637 | 2,295 | .00011 |
| 5800 | 25.756 | 138.4178 | 264.5067 | 126.3122 | 51.9469 | 5,235 | −.00759 | −7.3595 | 2,255 | .00020 |
| 5900 | 25.760 | 140.9936 | 267.0825 | 126.7525 | 51.0675 | 5,148 | −.00810 | −7.7419 | 2,216 | .00027 |
| 6000 | 25.763 | 143.5698 | 269.6587 | 127.1855 | 50.2176 | -------- | -------- | −8.1115 | -------- | -------- |

## TABLE XIX—THERMODYNAMIC PROPERTIES OF $B_2O_3$ (CRYSTAL)

[Molecular weight, 69.64]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | log $K$ |
|---|---|---|---|---|---|---|
| 0 | -------- | 0 | 48.6839 | -------- | -------- | -------- |
| 298.16 | 14.73 | 2.2410 | 50.9249 | 13.07 | 1137.336 | 455.554 |
| 300 | 14.79 | 2.2680 | 50.9519 | 13.16 | 1130.390 | 452.523 |
| 400 | 18.40 | 3.9240 | 52.6079 | 17.90 | 848.915 | 329.717 |
| 500 | 21.12 | 5.9080 | 54.5919 | 22.81 | 679.678 | 255.953 |
| 600 | 23.26 | 8.1300 | 56.8139 | 26.36 | 566.642 | 206.747 |
| 700 | 25.15 | 10.5520 | 59.2359 | 30.09 | 485.753 | 171.589 |
| 723.16 | 25.57 | 11.1400 | 59.8239 | 30.91 | 470.191 | 164.833 |

## TABLE XX—THERMODYNAMIC PROPERTIES OF $B_2O_3$ (LIQUID)

[Molecular weight, 69.64]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ (a) | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 723.16 | 31.75 | 16.5600 | 65.2439 | 38.41 | 466.420 | -------- | ---------- | 164.833 | -------- | ------------ |
| 800 | 31.660 | 18.9962 | 67.6801 | 41.6117 | 421.294 | -------- | ---------- | 145.334 | -------- | ------------ |
| 900 | 31.242 | 22.1413 | 70.8252 | 45.3166 | 374.121 | -------- | ---------- | 125.064 | -------- | ------------ |
| 1000 | 30.835 | 25.2452 | 73.9291 | 48.5872 | 336.4027 | 34,014 | −0.07512 | 108.8151 | 14,670 | −0.06036 |
| 1100 | 30.580 | 28.3159 | 76.9998 | 51.5141 | 306.5560 | 30,893 | −0.04637 | 95.5391 | 13,333 | −0.05693 |
| 1200 | 30.442 | 31.3670 | 80.0509 | 54.1690 | 279.8582 | 28,291 | −.02131 | 84.4852 | 12,216 | −.05142 |
| 1300 | 30.392 | 34.4067 | 83.0926 | 56.6037 | 258.1172 | 26,095 | −.00489 | 75.1397 | 11,271 | −.04681 |
| 1400 | 30.377 | 37.4472 | 86.1311 | 58.8554 | 239.4828 | 24,226 | −.00097 | 67.1358 | 10,462 | −.04377 |
| 1500 | 30.372 | 40.4846 | 89.1685 | 60.9511 | 223.3331 | 22,610 | −.00015 | 60.2049 | 9,760 | −.04040 |
| 1600 | 30.370 | 43.5217 | 92.2056 | 62.9112 | 209.2020 | 21,197 | −0.00022 | 54.1453 | 9,146 | −0.03770 |
| 1700 | 30.370 | 46.5587 | 95.2426 | 64.7523 | 196.7334 | 19,951 | −.00049 | 48.8030 | 8,605 | −.03586 |
| 1800 | 30.370 | 49.5957 | 98.2796 | 66.4882 | 185.6500 | 18,842 | −.00024 | 44.0583 | 8,123 | −.03346 |
| 1900 | 30.370 | 52.6327 | 101.8166 | 68.1308 | 175.7334 | 17,851 | −.00030 | 39.8165 | 7,692 | −.03150 |
| 2000 | 30.370 | 55.6697 | 104.3536 | 69.6880 | 166.8082 | 16,958 | −.00024 | 36.0020 | 7,304 | −.02990 |
| 2100 | 30.370 | 58.7067 | 107.3906 | 71.1698 | 158.7332 | 16,151 | −0.00036 | 32.5538 | 6,954 | −0.02861 |
| 2200 | 30.370 | 61.7437 | 110.4276 | 72.5826 | 151.3922 | 15,416 | −.00011 | 29.4215 | 6,635 | −.02738 |
| 2300 | 30.370 | 64.7807 | 113.4646 | 73.9326 | 144.6897 | 14,746 | −.00027 | 26.5641 | 6,344 | −.02613 |
| 2400 | 30.370 | 67.8177 | 116.5016 | 75.2251 | 138.5458 | 14,131 | −.00010 | 23.9469 | 6,077 | −.02500 |
| 2500 | 30.370 | 70.8547 | 119.5386 | 76.4649 | 132.8935 | -------- | ---------- | 21.5411 | -------- | ------------ |

a Enthalpy change in converting $B_2O_3$ (crystal) at 0° K to $B_2O_3$ (liquid) at temperature indicated.

## TABLE XXI—THERMODYNAMIC PROPERTIES OF C (GAS)

[Atomic weight, 12.010]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ |
|---|---|---|---|---|
| 0 | ---------- | 0 | 262.3181 | ---------- |
| 298.16 | 4.9803 | 1.5589 | 263.8770 | 37.7611 |
| 300 | 4.9801 | 1.5681 | 263.8862 | 37.7917 |
| 400 | 4.9747 | 2.0658 | 264.3539 | 39.2235 |
| 500 | 4.9723 | 2.5631 | 264.8812 | 40.3333 |
| 600 | 4.9709 | 3.0603 | 265.3784 | 41.2398 |
| 700 | 4.9701 | 3.5573 | 265.8754 | 42.0060 |
| 800 | 4.9697 | 4.0543 | 266.3724 | 42.6696 |
| 900 | 4.9693 | 4.5513 | 266.8694 | 43.2550 |
| 1000 | 4.9691 | 5.0482 | 267.3663 | 43.7785 |
| 1100 | 4.9691 | 5.5451 | 267.8632 | 44.2521 |
| 1200 | 4.9697 | 6.0421 | 268.3602 | 44.6845 |
| 1300 | 4.9705 | 6.5391 | 268.8572 | 45.0823 |
| 1400 | 4.9725 | 7.0362 | 269.3543 | 45.4507 |
| 1500 | 4.9747 | 7.5336 | 269.8517 | 45.7939 |
| 1600 | 4.9783 | 8.0312 | 270.3493 | 46.1150 |
| 1700 | 4.9835 | 8.5293 | 270.8474 | 46.4170 |
| 1800 | 4.9899 | 9.0280 | 271.3461 | 46.7020 |
| 1900 | 4.9980 | 9.5274 | 271.8455 | 46.9720 |
| 2000 | 5.0075 | 10.0277 | 272.3458 | 47.2287 |
| 2100 | 5.0189 | 10.5290 | 272.8471 | 47.4732 |
| 2200 | 5.0316 | 11.0315 | 273.3496 | 47.7070 |
| 2300 | 5.0455 | 11.5354 | 273.8535 | 47.9310 |
| 2400 | 5.0607 | 12.0407 | 274.3588 | 48.1460 |
| 2500 | 5.0769 | 12.5476 | 274.8657 | 48.3530 |
| 2600 | 5.0941 | 13.0561 | 275.3742 | 48.5524 |
| 2700 | 5.1118 | 13.5664 | 275.8845 | 48.7450 |
| 2800 | 5.1299 | 14.0785 | 276.3966 | 48.9312 |
| 2900 | 5.1486 | 14.5924 | 276.9105 | 49.1116 |
| 3000 | 5.1677 | 15.1082 | 277.4263 | 49.2864 |
| 3100 | 5.1866 | 15.6259 | 277.9440 | 49.4562 |
| 3200 | 5.2055 | 16.1455 | 278.4636 | 49.6212 |
| 3300 | 5.2243 | 16.6670 | 278.9851 | 49.7816 |
| 3400 | 5.2428 | 17.1904 | 279.5085 | 49.9379 |
| 3500 | 5.2610 | 17.7156 | 280.0337 | 50.0901 |
| 3600 | 5.2786 | 18.2426 | 280.5607 | 50.2386 |
| 3700 | 5.2959 | 18.7713 | 281.0894 | 50.3834 |
| 3800 | 5.3126 | 19.3017 | 281.6198 | 50.5249 |
| 3900 | 5.3286 | 19.8338 | 282.1519 | 50.6631 |
| 4000 | 5.3442 | 20.3674 | 282.6855 | 50.7982 |
| 4100 | 5.3590 | 20.9026 | 283.2207 | 50.9303 |
| 4200 | 5.3732 | 21.4392 | 283.7573 | 51.0596 |
| 4300 | 5.3866 | 21.9772 | 284.2953 | 51.1862 |
| 4400 | 5.3994 | 22.5165 | 284.8347 | 51.3102 |
| 4500 | 5.4115 | 23.0570 | 285.3571 | 51.4317 |
| 4600 | 5.4227 | 23.5987 | 285.9168 | 51.5508 |
| 4700 | 5.4331 | 24.1415 | 286.4596 | 51.6675 |
| 4800 | 5.4427 | 24.6853 | 287.0334 | 51.7820 |
| 4900 | 5.4514 | 25.2300 | 287.5481 | 51.8943 |
| 5000 | 5.4592 | 25.7755 | 288.0936 | 52.0045 |
| 5100 | 5.4661 | 26.3218 | 288.6399 | 52.1127 |
| 5200 | 5.4720 | 26.8687 | 289.1868 | 52.2189 |
| 5300 | 5.4770 | 27.4162 | 289.7343 | 52.3231 |
| 5400 | 5.4810 | 27.9641 | 290.2822 | 52.4256 |
| 5500 | 5.4841 | 28.5123 | 290.8304 | 52.5262 |
| 5600 | 5.4865 | 29.0608 | 291.3789 | 52.6250 |
| 5700 | 5.4882 | 29.6096 | 291.9277 | 52.7221 |
| 5800 | 5.4893 | 30.1585 | 292.4766 | 52.8176 |
| 5900 | 5.4898 | 30.7074 | 293.0255 | 52.9114 |
| 6000 | 5.4899 | 31.2564 | 293.5745 | 53.0037 |

## TABLE XXII—THERMODYNAMIC PROPERTIES OF CO (GAS)

[Molecular weight, 28.010]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ-H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | $\log K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | -------- | 0 | 65.7461 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.16 | 6.965 | 2.0727 | 67.8188 | 47.301 | 434.2122 | -------- | -------- | 182.2536 | -------- | -------- |
| 300 | 6.965 | 2.0855 | 67.8316 | 47.342 | 431.5591 | -------- | -------- | 181.0967 | -------- | -------- |
| 400 | 7.013 | 2.7838 | 68.5299 | 49.352 | 324.0685 | -------- | -------- | 134.2147 | -------- | -------- |
| 500 | 7.120 | 3.4900 | 69.2361 | 50.927 | 259.5584 | -------- | -------- | 106.0510 | -------- | -------- |
| 600 | 7.276 | 4.2095 | 69.9556 | 52.238 | 216.5368 | -------- | -------- | 87.2536 | -------- | -------- |
| 700 | 7.451 | 4.9458 | 70.6919 | 53.373 | 185.7931 | -------- | -------- | 73.8126 | -------- | -------- |
| 800 | 7.624 | 5.6998 | 71.4459 | 54.379 | 162.7232 | -------- | -------- | 63.7218 | -------- | -------- |
| 900 | 7.787 | 6.4706 | 72.2167 | 55.287 | 144.7699 | -------- | -------- | 55.8663 | -------- | -------- |
| 1000 | 7.932 | 7.2565 | 73.0026 | 56.1160 | 130.3992 | 12,904 | 0.03349 | 49.5767 | 5640 | 0.02293 |
| 1100 | 8.058 | 8.0560 | 73.8021 | 56.8779 | 118.6348 | 11,736 | 0.02870 | 44.4265 | 5131 | 0.01927 |
| 1200 | 8.167 | 8.8673 | 74.6134 | 57.5837 | 108.8261 | 10,762 | .02534 | 40.1314 | 4706 | .01680 |
| 1300 | 8.265 | 9.6889 | 75.4350 | 58.2413 | 100.5223 | 9,939 | .02161 | 36.4946 | 4346 | .01491 |
| 1400 | 8.349 | 10.5196 | 76.2657 | 58.8569 | 93.4014 | 9,235 | .01733 | 33.3754 | 4038 | .01310 |
| 1500 | 8.419 | 11.3580 | 77.1041 | 59.4353 | 87.2274 | 8,623 | .01492 | 30.6703 | 3771 | .01142 |
| 1600 | 8.481 | 12.2030 | 77.9491 | 59.9806 | 81.8231 | 8,087 | 0.01304 | 28.3020 | 3537 | 0.01031 |
| 1700 | 8.536 | 13.0538 | 78.7999 | 60.4964 | 77.0530 | 7,615 | .01094 | 26.2111 | 3330 | .00960 |
| 1800 | 8.585 | 13.9099 | 79.6560 | 60.9857 | 72.8115 | 7,196 | .00863 | 24.3515 | 3146 | .00891 |
| 1900 | 8.627 | 14.7705 | 80.5166 | 61.4510 | 69.0155 | 6,820 | .00720 | 22.6868 | 2982 | .00800 |
| 2000 | 8.665 | 15.6351 | 81.3812 | 61.8945 | 65.5983 | 6,482 | .00563 | 21.1878 | 2834 | .00748 |
| 2100 | 8.699 | 16.5033 | 82.2494 | 62.3181 | 62.5060 | 6,176 | 0.00443 | 19.8308 | 2700 | 0.00693 |
| 2200 | 8.730 | 17.3747 | 83.1208 | 62.7234 | 59.6943 | 5,898 | .00325 | 18.5906 | 2578 | .00653 |
| 2300 | 8.758 | 18.2491 | 83.9952 | 63.1121 | 57.1267 | 5,644 | .00213 | 17.4592 | 2467 | .00608 |
| 2400 | 8.784 | 19.1262 | 84.8723 | 63.4854 | 54.7729 | 5,412 | .00080 | 16.4352 | 2365 | .00580 |
| 2500 | 8.806 | 20.0057 | 85.7518 | 63.8444 | 52.6073 | 5,197 | .00025 | 15.4834 | 2271 | .00544 |
| 2600 | 8.827 | 20.8874 | 86.6335 | 64.1902 | 50.6082 | 4,999 | −0.00048 | 14.6045 | 2184 | 0.00531 |
| 2700 | 8.847 | 21.7711 | 87.5172 | 64.5238 | 48.7572 | 4,815 | −.00084 | 13.7903 | 2104 | .00507 |
| 2800 | 8.865 | 22.6567 | 88.4028 | 64.8458 | 47.0384 | 4,645 | −.00163 | 13.0338 | 2029 | .00494 |
| 2900 | 8.882 | 23.5440 | 89.2901 | 65.1572 | 45.4383 | 4,486 | −.00203 | 12.3292 | 1959 | .00490 |
| 3000 | 8.898 | 24.4330 | 90.1791 | 65.4586 | 43.9450 | 4,338 | −.00236 | 11.6713 | 1894 | .00483 |
| 3100 | 8.913 | 25.3246 | 91.0707 | 65.7506 | 42.5480 | 4,199 | −0.00289 | 11.0555 | 1834 | 0.00448 |
| 3200 | 8.927 | 26.2166 | 91.9627 | 66.0338 | 41.2387 | 4,070 | −.00353 | 10.4779 | 1777 | .00432 |
| 3300 | 8.939 | 27.1099 | 92.8560 | 66.3087 | 40.0089 | 3,948 | −.00339 | 9.9351 | 1723 | .00444 |
| 3400 | 8.952 | 28.0044 | 93.7505 | 66.5757 | 38.8517 | 3,832 | −.00386 | 9.4239 | 1673 | .00420 |
| 3500 | 8.963 | 28.9002 | 94.6463 | 66.8354 | 37.7607 | 3,723 | −.00417 | 8.9417 | 1626 | .00403 |
| 3600 | 8.974 | 29.7970 | 95.5431 | 67.0880 | 36.7307 | 3,619 | −0.00391 | 8.4860 | 1580 | 0.00417 |
| 3700 | 8.985 | 30.6950 | 96.4411 | 67.3340 | 35.7565 | 3,522 | −.00414 | 8.0548 | 1538 | .00406 |
| 3800 | 8.995 | 31.5940 | 97.3401 | 67.5738 | 34.8338 | 3,429 | −.00403 | 7.6460 | 1498 | .00390 |
| 3900 | 9.005 | 32.4940 | 98.2401 | 67.8076 | 33.9586 | 3,341 | −.00405 | 7.2580 | 1460 | .00380 |
| 4000 | 9.015 | 33.3950 | 99.1411 | 68.0357 | 33.1274 | 3,258 | −.00423 | 6.8892 | 1423 | .00393 |
| 4100 | 9.024 | 34.2969 | 100.0430 | 68.2584 | 32.3370 | 3,177 | −0.00383 | 6.5382 | 1389 | 0.00379 |
| 4200 | 9.034 | 35.1998 | 100.9459 | 68.4760 | 31.5844 | 3,103 | −.00423 | 6.2037 | 1356 | .00365 |
| 4300 | 9.042 | 36.1036 | 101.8497 | 68.6887 | 30.8670 | 3,030 | −.00394 | 5.8847 | 1325 | .00366 |
| 4400 | 9.051 | 37.0083 | 102.7544 | 68.8966 | 30.1823 | 2,961 | −.00400 | 5.5799 | 1295 | .00362 |
| 4500 | 9.059 | 37.9138 | 103.6599 | 69.1001 | 29.5283 | 2,895 | −.00395 | 5.2885 | 1266 | .00358 |
| 4600 | 9.067 | 38.8201 | 104.5662 | 69.2993 | 28.9029 | 2,832 | −0.00395 | 5.0097 | 1239 | 0.00358 |
| 4700 | 9.074 | 39.7271 | 105.4732 | 69.4944 | 28.3043 | 2,770 | −.00358 | 4.7425 | 1213 | .00349 |
| 4800 | 9.082 | 40.6349 | 106.3810 | 69.6855 | 27.7308 | 2,712 | −.00347 | 4.4863 | 1187 | .00356 |
| 4900 | 9.089 | 41.5435 | 107.2896 | 69.8728 | 27.1808 | 2,655 | −.00310 | 4.2405 | 1164 | .00340 |
| 5000 | 9.096 | 42.4527 | 108.1988 | 70.0565 | 26.6529 | 2,601 | −.00300 | 4.0043 | 1140 | .00347 |
| 5100 | 9.103 | 43.3627 | 109.1088 | 70.2367 | 26.1459 | 2,549 | −0.00279 | 3.7773 | 1118 | 0.00310 |
| 5200 | 9.110 | 44.2733 | 110.0194 | 70.4136 | 25.6585 | 2,499 | −.00261 | 3.5589 | 1097 | .00332 |
| 5300 | 9.117 | 45.1847 | 110.9308 | 70.5872 | 25.1896 | 2,451 | −.00239 | 3.3486 | 1077 | .00326 |
| 5400 | 9.123 | 46.0967 | 111.8428 | 70.7576 | 24.7381 | 2,403 | −.00201 | 3.1459 | 1057 | .00322 |
| 5500 | 9.130 | 47.0093 | 112.7554 | 70.9251 | 24.3032 | 2,358 | −.00167 | 2.9505 | 1037 | .00332 |
| 5600 | 9.137 | 47.9227 | 113.6688 | 71.0897 | 23.8838 | 2,316 | −0.00172 | 2.7620 | 1019 | 0.00333 |
| 5700 | 9.143 | 48.8367 | 114.5828 | 71.2514 | 23.4792 | 2,273 | −.00140 | 2.5799 | 1001 | .00321 |
| 5800 | 9.150 | 49.7513 | 115.4974 | 71.4105 | 23.0887 | 2,234 | −.00135 | 2.4041 | 984 | .00322 |
| 5900 | 9.156 | 50.6666 | 116.4127 | 71.5670 | 22.7114 | 2,196 | −.00130 | 2.2341 | 968 | .00317 |
| 6000 | 9.162 | 51.5825 | 117.3286 | 71.7209 | 22.3467 | -------- | -------- | 2.0696 | -------- | -------- |

## TABLE XXIII—THERMODYNAMIC PROPERTIES OF $CO_2$ (GAS)

[Molecular weight, 44.010]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta^\circ H}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | -------- | 0 | 0 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.16 | 8.874 | 2.2381 | 2.2381 | 51.061 | 648.2084 | -------- | -------- | 267.6053 | -------- | -------- |
| 300 | 8.894 | 2.2546 | 2.2546 | 51.116 | 644.2527 | -------- | -------- | 265.8787 | -------- | -------- |
| 400 | 9.871 | 3.1948 | 3.1948 | 53.815 | 483.9359 | -------- | -------- | 195.8795 | -------- | -------- |
| 500 | 10.662 | 4.2228 | 4.2228 | 56.113 | 287.6422 | -------- | -------- | 153.8214 | -------- | -------- |
| 600 | 11.311 | 5.3224 | 5.3224 | 58.109 | 323.3792 | -------- | -------- | 125.7469 | -------- | -------- |
| 700 | 11.849 | 6.4813 | 6.4813 | 59.895 | 277.4307 | -------- | -------- | 105.6751 | -------- | -------- |
| 800 | 12.300 | 7.6894 | 7.6894 | 61.507 | 242.9362 | -------- | -------- | 90.6086 | -------- | -------- |
| 900 | 12.678 | 8.9399 | 8.9399 | 62.980 | 216.0824 | -------- | -------- | 78.8821 | -------- | -------- |
| 1000 | 12.995 | 10.2220 | 10.2220 | 64.3310 | 194.5823 | 19,258 | 0.07095 | 69.4953 | 8428 | 0.02238 |
| 1100 | 13.265 | 11.5350 | 11.5350 | 65.5822 | 176.9768 | 17,548 | 0.05867 | 61.8111 | 7666 | 0.01797 |
| 1200 | 13.490 | 12.8728 | 12.8728 | 66.7461 | 162.2948 | 16,097 | .04919 | 55.4048 | 7031 | .01434 |
| 1300 | 13.680 | 14.2312 | 14.2312 | 67.8334 | 149.8633 | 14,868 | .04210 | 49.9820 | 6494 | .01103 |
| 1400 | 13.844 | 15.6074 | 15.6074 | 68.8532 | 139.2012 | 13,814 | .03647 | 45.3324 | 6033 | .00880 |
| 1500 | 13.988 | 16.9990 | 16.9990 | 69.8132 | 129.9554 | 12,900 | .03180 | 41.3016 | 5633 | .00718 |
| 1600 | 14.116 | 18.4042 | 18.4042 | 70.7200 | 121.8611 | 12,100 | 0.02796 | 37.7738 | 5283 | 0.00585 |
| 1700 | 14.230 | 19.8216 | 19.8216 | 71.5792 | 114.7155 | 11,395 | .02394 | 34.6603 | 4974 | .00467 |
| 1800 | 14.331 | 21.2496 | 21.2496 | 72.3955 | 108.3610 | 10,767 | .02116 | 31.8923 | 4699 | .00394 |
| 1900 | 14.421 | 22.6872 | 22.6872 | 73.1727 | 102.6730 | 10,206 | .01820 | 29.4152 | 4453 | .00320 |
| 2000 | 14.502 | 24.1334 | 24.1334 | 73.9145 | 97.5518 | 9,701 | .01548 | 27.1855 | 4231 | .00274 |
| 2100 | 14.576 | 25.5872 | 25.5872 | 74.6238 | 92.9168 | 9,244 | 0.01318 | 25.1680 | 4030 | 0.00248 |
| 2200 | 14.643 | 27.0482 | 27.0482 | 75.3034 | 88.7018 | 8,828 | .01124 | 23.3337 | 3848 | .00196 |
| 2300 | 14.705 | 28.5156 | 28.5156 | 75.9557 | 84.8523 | 8,447 | .01002 | 21.6587 | 3681 | .00175 |
| 2400 | 14.763 | 29.9690 | 29.9690 | 76.6828 | 81.3227 | 8,099 | .00850 | 20.1232 | 3529 | .00120 |
| 2500 | 14.817 | 31.4680 | 31.4680 | 77.1865 | 78.0746 | 7,778 | .00716 | 18.7104 | 3388 | .00112 |
| 2600 | 14.868 | 32.9522 | 32.9522 | 77.7687 | 75.0759 | 7,482 | 0.00599 | 17.4062 | 3258 | 0.00093 |
| 2700 | 14.916 | 34.4414 | 34.4414 | 78.3307 | 72.2688 | 7,208 | .00491 | 16.1966 | 3138 | .00069 |
| 2800 | 14.961 | 35.9353 | 35.9353 | 78.8740 | 69.7196 | 6,955 | .00322 | 15.0772 | 3026 | .00065 |
| 2900 | 15.003 | 37.4335 | 37.4335 | 79.3997 | 67.3181 | 6,717 | .00260 | 14.0331 | 2922 | .00060 |
| 3000 | 15.043 | 38.9358 | 38.9358 | 79.9090 | 65.0765 | 6,496 | .00172 | 13.0585 | 2825 | .00041 |
| 3100 | 15.081 | 40.4420 | 40.4420 | 80.4029 | 62.9793 | 6,289 | 0.00079 | 12.1468 | 2734 | 0.00032 |
| 3200 | 15.117 | 41.9519 | 41.9519 | 80.8822 | 61.0132 | 6,094 | .00048 | 11.2921 | 2649 | .00027 |
| 3300 | 15.152 | 43.4654 | 43.4654 | 81.3480 | 59.1661 | 5,912 | −.00052 | 10.4891 | 2568 | .00051 |
| 3400 | 15.185 | 44.9822 | 44.9822 | 81.8008 | 57.4278 | 5,740 | −.00100 | 9.7333 | 2493 | .00031 |
| 3500 | 15.216 | 46.5022 | 46.5022 | 82.2414 | 55.7888 | 5,578 | −.00154 | 9.0207 | 2421 | .00050 |
| 3600 | 15.246 | 48.0254 | 48.0254 | 82.6705 | 54.2409 | 5 424 | −0.00184 | 8.3477 | 2354 | 0.00048 |
| 3700 | 15.275 | 49.5514 | 49.5514 | 83.0886 | 52.7768 | 5,280 | −.00257 | 7.7110 | 2290 | .00047 |
| 3800 | 15.302 | 51.0802 | 51.0802 | 83.4963 | 51.3899 | 5,141 | −.00250 | 7.1079 | 2230 | .00051 |
| 3900 | 15.329 | 52.6118 | 52.6118 | 83.8941 | 50.0742 | 5,011 | −.00295 | 6.5356 | 2173 | .00045 |
| 4000 | 15.355 | 54.1460 | 54.1460 | 84.2826 | 48.8244 | 4,886 | −.00311 | 5.9919 | 2119 | .00037 |
| 4100 | 15.380 | 55.6828 | 55.6828 | 84.6620 | 47.6358 | 4,767 | −0.00310 | 5.4747 | 2067 | 0.00046 |
| 4200 | 15.405 | 57.2220 | 57.2220 | 85.0329 | 46.5039 | 4,654 | −.00322 | 4.9821 | 2018 | .00040 |
| 4300 | 15.429 | 58.7637 | 58.7637 | 85.3957 | 45.4248 | 4,546 | −.00318 | 4.5124 | 1970 | .00057 |
| 4400 | 15.452 | 60.3078 | 60.3078 | 85.7507 | 44.3948 | 4,443 | −.00333 | 4.0641 | 1926 | .00050 |
| 4500 | 15.475 | 61.8541 | 61.8541 | 86.0982 | 43.4108 | 4,343 | −.00313 | 3.6356 | 1883 | .00055 |
| 4600 | 15.496 | 63.4028 | 63.4028 | 86.4386 | 42.4698 | 4,249 | −0.00314 | 3.2257 | 1842 | 0.00049 |
| 4700 | 15.520 | 64.9536 | 64.9536 | 86.7721 | 41.5689 | 4,158 | −.00305 | 2.8333 | 1803 | .00048 |
| 4800 | 15.542 | 66.5068 | 66.5068 | 87.0991 | 40.7057 | 4,070 | −.00271 | 2.4572 | 1765 | .00060 |
| 4900 | 15.564 | 68.0620 | 68.0620 | 87.4198 | 39.8778 | 3,986 | −.00250 | 2.0964 | 1729 | .00068 |
| 5000 | 15.586 | 69.6196 | 69.6196 | 87.7344 | 39.0831 | 3,905 | −.00239 | 1.7500 | 1694 | .00064 |
| 5100 | 15.608 | 71.1792 | 71.1792 | 88.0433 | 38.3198 | 3,827 | −0.00196 | 1.4172 | 1661 | 0.00068 |
| 5200 | 15.630 | 72.7412 | 72.7412 | 88.3466 | 37.5858 | 3,752 | −.00172 | 1.0971 | 1629 | .00064 |
| 5300 | 15.652 | 74.3052 | 74.3052 | 88.6445 | 36.8796 | 3,680 | −.00158 | .7891 | 1598 | .00067 |
| 5400 | 15.674 | 75.8716 | 75.8716 | 88.9373 | 36.1997 | 3,610 | −.00116 | .4925 | 1568 | .00071 |
| 5500 | 15.696 | 77.4400 | 77.4400 | 89.2251 | 35.5445 | 3,543 | −.00088 | .2067 | 1540 | .00070 |
| 5600 | 15.718 | 79.0108 | 79.0108 | 89.5081 | 34.9127 | 3,478 | −0.00068 | −0.0690 | 1512 | 0.00074 |
| 5700 | 15.740 | 80.5836 | 80.5836 | 89.7865 | 34.3032 | 3,416 | −.00037 | −.3350 | 1486 | .00069 |
| 5800 | 15.762 | 82.1588 | 82.1588 | 90.0604 | 33.7146 | 3,356 | −.00031 | −.5919 | 1460 | .00074 |
| 5900 | 15.784 | 83.7360 | 83.7360 | 90.3301 | 33.1461 | 3,298 | −.00007 | −.8401 | 1435 | .00073 |
| 6000 | 15.806 | 85.3156 | 85.3056 | 90.5955 | 32.5965 | -------- | -------- | −1.0600 | -------- | -------- |

## TABLE XXIV—THERMODYNAMIC PROPERTIES OF Cl (GAS)

[Atomic weight, 35.457]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ |
|---|---|---|---|---|
| 0 | ---------- | 0 | 32.5131 | ---------- |
| 298.16 | 5.2203 | 1.4991 | 34.0122 | 39.4569 |
| 300 | 5.2237 | 1.5087 | 34.0218 | 39.4890 |
| 400 | 5.3705 | 2.0391 | 34.5522 | 41.0138 |
| 500 | 5.4363 | 2.5801 | 35.0932 | 42.2206 |
| 600 | 5.4448 | 3.1244 | 35.6375 | 43.2132 |
| 700 | 5.4232 | 3.6680 | 36.1811 | 44.0511 |
| 800 | 5.3887 | 4.2086 | 36.7217 | 44.7731 |
| 900 | 5.3506 | 4.7456 | 37.2587 | 45.4056 |
| 1000 | 5.3133 | 5.2788 | 37.7919 | 45.9674 |
| 1100 | 5.2788 | 5.8084 | 38.3215 | 46.4722 |
| 1200 | 5.2477 | 6.3347 | 38.8478 | 46.9302 |
| 1300 | 5.2201 | 6.8581 | 39.3712 | 47.3491 |
| 1400 | 5.1958 | 7.3789 | 39.8920 | 47.7351 |
| 1500 | 5.1745 | 7.8974 | 40.4105 | 48.0928 |
| 1600 | 5.1557 | 8.4139 | 40.9270 | 48.4262 |
| 1700 | 5.1392 | 8.9286 | 41.4417 | 48.7383 |
| 1800 | 5.1246 | 9.4418 | 41.9549 | 49.0316 |
| 1900 | 5.1117 | 9.9536 | 42.4667 | 49.3083 |
| 2000 | .1002 | 10.4642 | 42.9773 | 49.5702 |
| 2100 | 5.0900 | 10.9737 | 43.4868 | 49.8188 |
| 2200 | 5.0809 | 11.4823 | 43.9954 | 50.0554 |
| 2300 | 5.0727 | 11.9900 | 44.5031 | 50.2811 |
| 2400 | 5.0654 | 12.4969 | 45.0100 | 50.4968 |
| 2500 | 5.0588 | 13.0031 | 45.5162 | 50.7034 |
| 2600 | 5.0528 | 13.5087 | 46.0218 | 50.9017 |
| 2700 | 5.0474 | 14.0137 | 46.5268 | 51.0923 |
| 2800 | 5.0425 | 14.5182 | 47.0313 | 51.2758 |
| 2900 | 5.0380 | 15.0222 | 47.5353 | 51.4527 |
| 3000 | 5.0339 | 15.5258 | 48.0389 | 51.6234 |
| 3100 | 5.0301 | 16.0290 | 48.5421 | 51.7884 |
| 3200 | 5.0267 | 16.5318 | 49.0449 | 51.9480 |
| 3300 | 5.0235 | 17.0343 | 49.5474 | 52.1027 |
| 3400 | 5.0206 | 17.5365 | 50.0496 | 52.2526 |
| 3500 | 5.0179 | 18.0385 | 50.5516 | 52.3981 |
| 3600 | 5.0154 | 18.5401 | 51.0532 | 52.5394 |
| 3700 | 5.0131 | 19.0416 | 51.5547 | 52.6768 |
| 3800 | 5.0109 | 19.5428 | 52.0559 | 52.8105 |
| 3900 | 5.0089 | 20.0437 | 52.5568 | 52.9406 |
| 4000 | 5.0070 | 20.5445 | 53.0576 | 53.0674 |
| 4100 | 5.0052 | 21.0452 | 53.5583 | 53.1910 |
| 4200 | 5.0035 | 21.5456 | 54.0587 | 53.3116 |
| 4300 | 5.0020 | 22.0459 | 54.5590 | 53.4293 |
| 4400 | 5.0006 | 22.5460 | 55.0591 | 53.5443 |
| 4500 | 4.9993 | 23.0460 | 55.5591 | 53.6566 |
| 4600 | 4.9981 | 23.5459 | 56.0590 | 53.7665 |
| 4700 | 4.9970 | 24.0456 | 56.5587 | 53.8740 |
| 4800 | 4.9960 | 24.5453 | 57.0584 | 53.9792 |
| 4900 | 4.9950 | 25.0448 | 57.5579 | 54.0822 |
| 5000 | 4.9941 | 25.5443 | 58.0574 | 54.1831 |
| 5100 | 4.9932 | 26.0436 | 58.5567 | 54.2820 |
| 5200 | 4.9924 | 26.5429 | 59.0560 | 54.3789 |
| 5300 | 4.9916 | 27.0421 | 59.5552 | 54.4740 |
| 5400 | 4.9908 | 27.5412 | 60.0543 | 54.5673 |
| 5500 | 4.9901 | 28.0403 | 60.5534 | 54.6589 |
| 5600 | 4.9894 | 28.5393 | 61.0524 | 54.7486 |
| 5700 | 4.9887 | 29.0382 | 61.5513 | 54.8371 |
| 5800 | 4.9880 | 29.5370 | 62.0501 | 54.9239 |
| 5900 | 4.9873 | 30.0358 | 62.5489 | 55.0091 |
| 6000 | 4.9866 | 30.5345 | 63.0476 | 55.0929 |

## TABLE XXV—THERMODYNAMIC PROPERTIES OF $Cl_2$ (GAS)

[Molecular weight, 70.914]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $\frac{\Delta H^\circ}{RT}$ | $\delta\left(\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | -------- | 0 | 7.8061 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.16 | 8.11 | 2.1939 | 10.0000 | 53.286 | 97.9319 | -------- | -------- | 36.9304 | -------- | -------- |
| 300 | 8.12 | 2.2089 | 10.0150 | 53.336 | 97.3383 | -------- | -------- | 36.6695 | -------- | -------- |
| 400 | 8.44 | 3.0384 | 10.8445 | 55.720 | 73.2947 | -------- | -------- | 26.0820 | -------- | -------- |
| 500 | 8.62 | 3.8920 | 11.6981 | 57.625 | 58.8656 | -------- | -------- | 19.7044 | -------- | -------- |
| 600 | 8.74 | 4.7610 | 12.5671 | 59.207 | 49.2389 | -------- | -------- | 15.4354 | -------- | -------- |
| 700 | 8.82 | 5.6399 | 13.4460 | 60.562 | 42.3545 | -------- | -------- | 12.3755 | -------- | -------- |
| 800 | 8.88 | 6.5248 | 14.3309 | 61.744 | 37.1837 | -------- | -------- | 10.0725 | -------- | -------- |
| 900 | 8.92 | 7.4142 | 15.2203 | 62.792 | 33.1554 | -------- | -------- | 8.2757 | -------- | -------- |
| 1000 | 8.96 | 8.3090 | 16.1151 | 63.7350 | 29.9262 | 2884 | 0.02478 | 6.8337 | 1282 | 0.01765 |
| 1100 | 8.99 | 9.2065 | 17.0126 | 64.5904 | 27.2796 | 2624 | 0.02283 | 5.6506 | 1168 | 0.01517 |
| 1200 | 9.02 | 10.1070 | 17.9131 | 65.3739 | 25.0701 | 2410 | .01895 | 4.6621 | 1073 | .01312 |
| 1300 | 9.04 | 11.0100 | 18.8161 | 66.0967 | 23.1973 | 2227 | .01719 | 3.8236 | 992 | .01183 |
| 1400 | 9.06 | 11.9150 | 19.7211 | 66.7674 | 21.5894 | 2070 | .01570 | 3.1032 | 923 | .01047 |
| 1500 | 9.08 | 12.8220 | 20.6281 | 67.3931 | 20.1937 | 1930 | .01695 | 2.4774 | 863 | .00923 |
| 1600 | 9.109 | 13.7315 | 21.5376 | 67.9800 | 18.9705 | 1817 | 0.01228 | 1.9268 | 810 | 0.00863 |
| 1700 | 9.124 | 14.6431 | 22.4492 | 68.5327 | 17.8894 | 1712 | .01109 | 1.4437 | 764 | .00766 |
| 1800 | 9.139 | 15.5563 | 23.3624 | 69.0547 | 16.9272 | 1618 | .01042 | 1.0116 | 722 | .00720 |
| 1900 | 9.155 | 16.4709 | 24.2770 | 69.5492 | 16.0652 | 1534 | .00990 | .6244 | 686 | .00620 |
| 2000 | 9.171 | 17.3873 | 25.1934 | 70.0192 | 15.2883 | 1460 | .00856 | .2752 | 653 | .00545 |
| 2100 | 9.185 | 18.3051 | 26.1112 | 70.4670 | 14.5845 | 1391 | 0.00623 | −0.0412 | 623 | 0.00492 |
| 2200 | 9.200 | 19.2243 | 27.0304 | 70.8946 | 13.9440 | 1329 | .00767 | −.3293 | 595 | .00450 |
| 2300 | 9.215 | 20.1451 | 27.9512 | 71.3039 | 13.3585 | 1272 | .00740 | −.5928 | 570 | .00440 |
| 2400 | 9.230 | 21.0673 | 28.8734 | 71.6964 | 12.8211 | 1220 | .00700 | −.8347 | 547 | .00410 |
| 2500 | 9.244 | 21.9910 | 29.7971 | 72.0735 | 12.3261 | 1172 | .00663 | −1.0576 | 526 | .00379 |
| 2600 | 9.259 | 22.9161 | 30.7222 | 72.4364 | 11.8687 | 1128 | 0.00632 | −1.2637 | 506 | 0.00359 |
| 2700 | 9.273 | 23.8427 | 31.6488 | 72.7860 | 11.4446 | 1087 | .00599 | −1.4547 | 488 | .00331 |
| 2800 | 9.287 | 24.7707 | 32.5768 | 73.1235 | 11.0504 | 1049 | .00568 | −1.6323 | 471 | .00319 |
| 2900 | 9.300 | 25.7001 | 33.5062 | 73.4497 | 10.6830 | 1012 | .00597 | −1.7979 | 456 | .00280 |
| 3000 | 9.315 | 26.6309 | 34.4370 | 73.7652 | 10.3397 | 981 | .00495 | −1.9527 | 441 | .00264 |
| 3100 | 9.327 | 27.5629 | 35.3690 | 74.0708 | 10.0188 | 949 | 0.00514 | −2.0976 | 427 | 0.00256 |
| 3200 | 9.341 | 28.4963 | 36.3024 | 74.3672 | 9.7166 | 919 | .00532 | −2.2336 | 415 | .00224 |
| 3300 | 9.355 | 29.4311 | 37.2372 | 74.6548 | 9.4328 | 893 | .00465 | −2.3616 | 402 | .00226 |
| 3400 | 9.368 | 30.3673 | 38.1734 | 74.9343 | 9.1655 | 866 | .00457 | −2.4821 | 391 | .00209 |
| 3500 | 9.382 | 31.3048 | 39.1109 | 75.2060 | 8.9132 | 843 | .00443 | −2.5959 | 381 | .00177 |
| 3600 | 9.395 | 32.2437 | 40.0498 | 75.4705 | 8.6746 | 819 | 0.00455 | −2.7035 | 371 | 0.00163 |
| 3700 | 9.409 | 33.1839 | 40.9900 | 75.7281 | 8.4487 | 798 | .00430 | −2.8054 | 361 | .00160 |
| 3800 | 9.422 | 34.1254 | 41.9315 | 75.9792 | 8.2344 | 776 | .00453 | −2.9020 | 352 | .00144 |
| 3900 | 9.436 | 35.0683 | 42.8744 | 76.2241 | 8.0309 | 758 | .00410 | −2.9937 | 343 | .00155 |
| 4000 | 9.448 | 36.0125 | 43.8186 | 76.4632 | 7.8373 | 739 | .00406 | −3.0810 | 334 | .00154 |
| 4100 | 9.461 | 36.9579 | 44.7640 | 76.6966 | 7.6530 | 721 | 0.00403 | −3.1640 | 327 | 0.00134 |
| 4200 | 9.474 | 37.9047 | 45.7108 | 76.9248 | 7.4773 | 703 | .00431 | −3.2432 | 319 | .00131 |
| 4300 | 9.488 | 38.8528 | 46.6589 | 77.1479 | 7.3095 | 688 | .00394 | −3.3187 | 312 | .00129 |
| 4400 | 9.501 | 39.8023 | 47.6084 | 77.3662 | 7.1492 | 672 | .00397 | −3.3909 | 305 | .00122 |
| 4500 | 9.514 | 40.7530 | 48.5591 | 77.5798 | 6.9959 | 658 | .00386 | −3.4599 | 299 | .00110 |
| 4600 | 9.527 | 41.7051 | 49.5112 | 77.7891 | 6.8490 | 644 | 0.00378 | −3.5260 | 292 | 0.00117 |
| 4700 | 9.540 | 42.6584 | 50.4645 | 77.9941 | 6.7082 | 630 | .00385 | −3.5893 | 286 | .00112 |
| 4800 | 9.553 | 43.6131 | 51.4192 | 78.1951 | 6.5731 | 617 | .00378 | −3.6500 | 281 | .00095 |
| 4900 | 9.566 | 44.5690 | 52.3751 | 78.3922 | 6.4434 | 605 | .00370 | −3.7083 | 275 | .00100 |
| 5000 | 9.579 | 45.5263 | 53.3324 | 78.5856 | 6.3187 | 593 | .00363 | −3.7643 | 270 | .00086 |
| 5100 | 9.592 | 46.4868 | 54.2909 | 78.7754 | 6.1988 | 581 | 0.00377 | −3.8181 | 265 | 0.00084 |
| 5200 | 9.605 | 47.4447 | 55.2508 | 78.9618 | 6.0833 | 569 | .00384 | −3.8699 | 260 | .00084 |
| 5300 | 9.619 | 48.4059 | 56.2120 | 79.1449 | 5.9721 | 559 | .00378 | −3.9196 | 255 | .00078 |
| 5400 | 9.632 | 49.3684 | 57.1745 | 79.3248 | 5.8648 | 549 | .00368 | −3.9678 | 250 | .00085 |
| 5500 | 9.645 | 50.3323 | 58.1384 | 79.5016 | 5.7613 | 539 | .00365 | −4.0141 | 246 | .00077 |
| 5600 | 9.658 | 51.2974 | 59.1035 | 79.6755 | 5.6614 | 530 | 0.00362 | −4.0558 | 242 | 0.00074 |
| 5700 | 9.671 | 52.2639 | 60.0700 | 79.8466 | 5.5648 | 520 | .00364 | −4.1020 | 238 | .00067 |
| 5800 | 9.684 | 53.2316 | 61.0377 | 80.0149 | 5.4715 | 511 | .00369 | −4.1437 | 233 | .00071 |
| 5900 | 9.697 | 54.2007 | 62.0068 | 80.1806 | 5.3812 | 503 | .00357 | −4.1839 | 230 | .00067 |
| 6000 | 9.710 | 55.1660 | 62.9771 | 80.3436 | 5.2938 | -------- | -------- | −4.2229 | -------- | -------- |

## TABLE XXVI—THERMODYNAMIC PROPERTIES OF ClF (GAS)

[Molecular weight, 54.457]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{cal}{mole\ °K}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{kcal}{mole}\right)$ | $H_T^\circ$ $\left(\frac{kcal}{mole}\right)$ | $S_T^\circ$ $\left(\frac{cal}{mole\ °K}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ $a$ | $b$ | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ $c$ | $d$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | ------ | 0 | 21.2069 | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| 298.16 | 7.6517 | 2.1281 | 23.3350 | 52.0438 | 102.1326 | ------ | ------ | 38.8196 | ------ | ------ |
| 300 | 7.6599 | 2.1422 | 23.3491 | 52.0904 | 101.5154 | ------ | ------ | 38.5476 | ------ | ------ |
| 400 | 8.0382 | 2.9283 | 24.1351 | 54.3491 | 76.4945 | ------ | ------ | 27.5018 | ------ | ------ |
| 500 | 8.2920 | 3.7456 | 24.9525 | 56.1720 | 61.4528 | ------ | ------ | 20.8444 | ------ | ------ |
| 600 | 8.4594 | 4.5838 | 25.7907 | 57.6997 | 51.4044 | ------ | ------ | 16.3882 | ------ | ------ |
| 700 | 8.5723 | 5.4357 | 26.6426 | 59.0127 | 44.2125 | ------ | ------ | 13.1937 | ------ | ------ |
| 800 | 8.6511 | 6.2971 | 27.5040 | 60.1628 | 38.8061 | ------ | ------ | 10.7898 | ------ | ------ |
| 900 | 8.7077 | 7.1652 | 28.3721 | 61.1852 | 34.5972 | ------ | ------ | 8.9145 | ------ | ------ |
| 1000 | 8.7496 | 8.0381 | 29.2450 | 62.1049 | 31.2228 | 3018 | 0.02146 | 7.4100 | 1337 | 0.01885 |
| 1100 | 8.7814 | 8.9147 | 30.1216 | 62.9404 | 28.4577 | 2748 | 0.01730 | 6.1757 | 1218 | 0.01020 |
| 1200 | 8.8060 | 9.7940 | 31.0009 | 63.7055 | 26.1504 | 2522 | .01490 | 5.1445 | 1119 | .01383 |
| 1300 | 8.8255 | 10.6756 | 31.8825 | 64.4111 | 24.1955 | 2331 | .01250 | 4.2699 | 1035 | .01211 |
| 1400 | 8.8411 | 11.5589 | 32.7658 | 65.0657 | 22.5180 | 2167 | .01073 | 3.5185 | 962 | .01127 |
| 1500 | 8.8538 | 12.4437 | 33.6506 | 65.6761 | 21.0626 | 2025 | .00908 | 2.8659 | 900 | .00980 |
| 1600 | 8.8644 | 13.3296 | 34.5365 | 66.2479 | 19.7879 | 1901 | 0.00747 | 2.2936 | 845 | 0.00904 |
| 1700 | 8.8732 | 14.2165 | 35.4234 | 66.7855 | 18.6622 | 1790 | .00696 | 1.7875 | 796 | .00848 |
| 1800 | 8.8808 | 15.1042 | 36.3111 | 67.2929 | 17.6606 | 1692 | .00617 | 1.3368 | 753 | .00778 |
| 1900 | 8.8875 | 15.9926 | 37.1995 | 67.7733 | 16.7641 | 1605 | .00500 | .9327 | 714 | .00730 |
| 2000 | 8.8937 | 16.8817 | 38.0886 | 68.2293 | 15.9566 | 1525 | .00491 | .5684 | 680 | .00649 |
| 2100 | 8.8997 | 17.7713 | 38.9782 | 68.6634 | 15.2255 | 1453 | 0.00465 | 0.2381 | 648 | 0.00635 |
| 2200 | 8.9059 | 18.6616 | 39.8685 | 69.0775 | 14.5604 | 1388 | .00412 | −.0628 | 619 | .00607 |
| 2300 | 8.9126 | 19.5525 | 40.7594 | 69.4736 | 13.9528 | 1327 | .00448 | −.3380 | 593 | .00562 |
| 2400 | 8.9202 | 20.4442 | 41.6511 | 69.8530 | 13.3954 | 1272 | .00430 | −.5907 | 569 | .00530 |
| 2500 | 8.9291 | 21.3366 | 42.5435 | 70.2174 | 12.8823 | 1220 | .00477 | −.8236 | 547 | .00492 |
| 2600 | 8.9398 | 22.2301 | 43.4370 | 70.5678 | 12.4083 | 1173 | 0.00476 | −1.0389 | 527 | 0.00461 |
| 2700 | 8.9525 | 23.1247 | 44.3316 | 70.9054 | 11.9691 | 1128 | .00534 | −1.2387 | 508 | .00437 |
| 2800 | 8.9678 | 24.0207 | 45.2276 | 71.2313 | 11.5609 | 1086 | .00602 | −1.4245 | 490 | .00433 |
| 2900 | 8.9858 | 24.9184 | 46.1253 | 71.5463 | 11.1804 | 1047 | .00650 | −1.5978 | 474 | .00390 |
| 3000 | 9.0072 | 25.8180 | 47.0249 | 71.8513 | 10.8249 | 1009 | .00762 | −1.7597 | 459 | .00374 |
| 3100 | 9.0320 | 26.7200 | 47.9269 | 72.1470 | 10.4918 | 974 | 0.00832 | −1.9115 | 445 | 0.00344 |
| 3200 | 9.0606 | 27.6246 | 48.8315 | 72.4342 | 10.1791 | 941 | .00915 | −2.0540 | 432 | .00319 |
| 3300 | 9.0932 | 28.5323 | 49.7392 | 72.7135 | 9.8848 | 909 | .01015 | −2.1881 | 419 | .00306 |
| 3400 | 9.1299 | 29.4435 | 50.6504 | 72.9855 | 9.6073 | 879 | .01116 | −2.3144 | 406 | .00273 |
| 3500 | 9.1709 | 30.3585 | 51.5654 | 73.2508 | 9.3450 | 850 | .01229 | −2.4337 | 397 | .00252 |
| 3600 | 9.2162 | 31.2779 | 52.4848 | 73.5098 | 9.0966 | 823 | 0.01317 | −2.5465 | 387 | 0.00221 |
| 3700 | 9.2658 | 32.2020 | 53.4089 | 73.7630 | 8.8610 | 797 | .01416 | −2.6533 | 377 | .00219 |
| 3800 | 9.3197 | 33.1312 | 54.3381 | 74.0108 | 8.6371 | 772 | .01535 | −2.7547 | 368 | .00184 |
| 3900 | 9.3778 | 34.0661 | 55.2730 | 74.2536 | 8.4238 | 749 | .01605 | −2.8509 | 359 | .00175 |
| 4000 | 9.4399 | 35.0070 | 56.2139 | 74.4918 | 8.2205 | 726 | .01713 | −2.9424 | 351 | .00149 |
| 4100 | 9.5059 | 35.9543 | 57.1612 | 74.7257 | 8.0263 | 705 | 0.01804 | −3.0295 | 343 | 0.00133 |
| 4200 | 9.5754 | 36.9084 | 58.1153 | 74.9556 | 7.8404 | 684 | .01893 | −3.1125 | 336 | .00100 |
| 4300 | 9.6485 | 37.8696 | 59.0765 | 75.1818 | 7.6624 | 666 | .01954 | −3.1917 | 329 | .00093 |
| 4400 | 9.7246 | 38.8382 | 60.0451 | 75.4045 | 7.4915 | 647 | .02032 | −3.2674 | 322 | .00074 |
| 4500 | 9.8035 | 39.8146 | 61.0215 | 75.6239 | 7.3274 | 630 | .02084 | −3.3397 | 316 | .00050 |
| 4600 | 9.8849 | 40.7990 | 62.0059 | 75.8403 | 7.1696 | 614 | 0.02146 | −3.4089 | 310 | 0.00024 |
| 4700 | 9.9686 | 41.7917 | 62.9986 | 76.0538 | 7.0175 | 599 | .02181 | −3.4751 | 305 | −.00004 |
| 4800 | 10.0539 | 42.7928 | 63.9997 | 76.2645 | 6.8709 | 585 | .02221 | −3.5386 | 299 | −.00012 |
| 4900 | 10.1407 | 43.8026 | 65.0095 | 76.4727 | 6.7293 | 572 | .02230 | −3.5995 | 294 | −.00030 |
| 5000 | 10.2287 | 44.8210 | 66.0279 | 76.6785 | 6.5926 | 560 | .02250 | −3.6580 | 289 | −.00057 |
| 5100 | 10.3173 | 45.8483 | 67.0552 | 76.8819 | 6.4603 | 548 | 0.02272 | −3.7141 | 284 | −0.00072 |
| 5200 | 10.4064 | 46.8845 | 68.0914 | 77.0831 | 6.3322 | 538 | .02259 | −3.7680 | 280 | −.00093 |
| 5300 | 10.4955 | 47.9296 | 69.1365 | 77.2822 | 6.2081 | 528 | .02252 | −3.8199 | 275 | −.00103 |
| 5400 | 10.5844 | 48.9836 | 70.1905 | 77.4792 | 6.0878 | 519 | .02244 | −3.8698 | 270 | −.00109 |
| 5500 | 10.6725 | 50.0465 | 71.2534 | 77.6742 | 5.9710 | 511 | .02215 | −3.9178 | 267 | −.00138 |
| 5600 | 10.7597 | 51.1181 | 72.3250 | 77.8673 | 5.8576 | 504 | 0.02178 | −3.9641 | 263 | −0.00154 |
| 5700 | 10.8457 | 52.1983 | 73.4052 | 78.0585 | 5.7474 | 497 | .02141 | −4.0067 | 259 | −.00156 |
| 5800 | 10.9302 | 53.2871 | 74.4940 | 78.2478 | 5.6403 | 491 | .02098 | −4.0518 | 255 | −.00182 |
| 5900 | 11.0129 | 54.3843 | 75.5912 | 78.4354 | 5.5361 | 485 | .02067 | −4.0932 | 252 | −.00190 |
| 6000 | 11.0937 | 55.4896 | 76.6965 | 78.6212 | 5.4346 | ------ | ------ | −4.1333 | ------ | ------ |

TABLE XXVII—THERMODYNAMIC PROPERTIES OF F (GAS)

[Molecular weight, 19.00]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ |
|---|---|---|---|---|
| 0 | ---------- | 0 | 48.2781 | ---------- |
| 298.16 | 5.4364 | 1.5580 | 49.8361 | 37.9173 |
| 300 | 5.4355 | 1.5680 | 49.8461 | 37.9507 |
| 400 | 5.3612 | 2.1081 | 50.3862 | 39.5050 |
| 500 | 5.2819 | 2.6401 | 50.9182 | 40.6926 |
| 600 | 5.2179 | 3.1650 | 51.4431 | 41.6497 |
| 700 | 5.1692 | 3.6842 | 51.9623 | 42.4502 |
| 800 | 5.1324 | 4.1992 | 52.4773 | 43.1379 |
| 900 | 5.1043 | 4.7110 | 52.9891 | 43.7407 |
| 1000 | 5.0826 | 5.2203 | 53.4984 | 44.2774 |
| 1100 | 5.0655 | 5.7277 | 54.0058 | 44.7610 |
| 1200 | 5.0519 | 6.2336 | 54.5117 | 45.2012 |
| 1300 | 5.0409 | 6.7382 | 55.0163 | 45.6051 |
| 1400 | 5.0318 | 7.2419 | 55.5200 | 45.9783 |
| 1500 | 5.0244 | 7.7447 | 56.0228 | 46.3252 |
| 1600 | 5.0181 | 8.2468 | 56.5249 | 46.6493 |
| 1700 | 5.0129 | 8.7483 | 57.0264 | 46.9534 |
| 1800 | 5.0084 | 9.2494 | 57.5275 | 47.2398 |
| 1900 | 5.0045 | 9.7501 | 58.0282 | 47.5105 |
| 2000 | 5.0012 | 10.2503 | 58.5284 | 47.7671 |
| 2100 | 4.9983 | 10.7503 | 59.0284 | 48.0110 |
| 2200 | 4.9957 | 11.2500 | 59.5281 | 48.2435 |
| 2300 | 4.9935 | 11.7495 | 60.0276 | 48.4655 |
| 2400 | 4.9915 | 12.2487 | 60.5268 | 48.6780 |
| 2500 | 4.9898 | 12.7478 | 61.0259 | 48.8817 |
| 2600 | 4.9882 | 13.2467 | 61.5248 | 49.0774 |
| 2700 | 4.9868 | 13.7454 | 62.0235 | 49.2656 |
| 2800 | 4.9855 | 14.2441 | 62.5222 | 49.4469 |
| 2900 | 4.9844 | 14.7425 | 63.0206 | 49.6219 |
| 3000 | 4.9834 | 15.2409 | 63.5190 | 49.7908 |
| 3100 | 4.9824 | 15.7392 | 64.0173 | 49.9542 |
| 3200 | 4.9816 | 16.2374 | 64.5155 | 50.1124 |
| 3300 | 4.9808 | 16.7355 | 65.0136 | 50.2657 |
| 3400 | 4.9801 | 17.2336 | 65.5117 | 50.4143 |
| 3500 | 4.9794 | 17.7316 | 66.0097 | 50.5587 |
| 3600 | 4.9788 | 18.2295 | 66.5076 | 50.6990 |
| 3700 | 4.9782 | 18.7273 | 67.0054 | 50.8354 |
| 3800 | 4.9777 | 19.2251 | 67.5032 | 50.9681 |
| 3900 | 4.9772 | 19.7229 | 68.0010 | 51.0974 |
| 4000 | 4.9768 | 20.2206 | 68.4987 | 51.2234 |
| 4100 | 4.9764 | 20.7182 | 68.9963 | 51.3463 |
| 4200 | 4.9760 | 21.2158 | 69.4939 | 51.4662 |
| 4300 | 4.9756 | 21.7134 | 69.9915 | 51.5833 |
| 4400 | 4.9753 | 22.2110 | 70.4891 | 51.6977 |
| 4500 | 4.9750 | 22.7085 | 70.9866 | 51.8095 |
| 4600 | 4.9747 | 23.2060 | 71.4841 | 51.9188 |
| 4700 | 4.9744 | 23.7034 | 71.9815 | 52.0258 |
| 4800 | 4.9741 | 24.2009 | 72.4790 | 52.1305 |
| 4900 | 4.9739 | 24.6983 | 72.9764 | 52.2331 |
| 5000 | 4.9737 | 25.1956 | 73.4737 | 52.3336 |
| 5100 | 4.9735 | 25.6930 | 73.9711 | 52.4320 |
| 5200 | 4.9732 | 26.1903 | 74.4684 | 52.5286 |
| 5300 | 4.9731 | 26.6876 | 74.9657 | 52.6234 |
| 5400 | 4.9729 | 27.1849 | 75.4630 | 52.7163 |
| 5500 | 4.9727 | 27.6822 | 75.9603 | 52.8076 |
| 5600 | 4.9725 | 28.1795 | 76.4576 | 52.8972 |
| 5700 | 4.9724 | 28.6767 | 76.9548 | 52.9852 |
| 5800 | 4.9723 | 29.1740 | 77.4521 | 53.0716 |
| 5900 | 4.9721 | 29.6712 | 77.9493 | 53.1566 |
| 6000 | 4.9720 | 30.1684 | 78.4465 | 53.2402 |

## TABLE XXVIII—THERMODYNAMIC PROPERTIES OF $F_2$ (GAS)

[Molecular weight, 38.00]

| $T$ (°K) | $C^\circ_p$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H^\circ_T-H^\circ_0$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H^\circ_T$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S^\circ_T$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | ------ | 0 | 60.9562 | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| 298.16 | 7.5183 | 2.1137 | 63.0699 | 48.5590 | 61.7763 | ------ | ------ | 20.8681 | ------ | ------ |
| 300 | 7.5262 | 2.1276 | 63.0838 | 48.6053 | 61.4076 | ------ | ------ | 20.7035 | ------ | ------ |
| 400 | 7.9077 | 2.9001 | 63.8563 | 50.8251 | 46.4428 | ------ | ------ | 14.0101 | ------ | ------ |
| 500 | 8.1822 | 3.7055 | 64.6617 | 52.6211 | 37.4145 | ------ | ------ | 9.9626 | ------ | ------ |
| 600 | 8.3704 | 4.5337 | 65.4899 | 54.1306 | 31.3646 | ------ | ------ | 7.2467 | ------ | ------ |
| 700 | 8.5004 | 5.3776 | 66.3338 | 55.4313 | 27.0238 | ------ | ------ | 5.2959 | ------ | ------ |
| 800 | 8.5924 | 6.2325 | 67.1887 | 56.5727 | 23.7560 | ------ | ------ | 3.8255 | ------ | ------ |
| 900 | 8.6593 | 7.0953 | 68.0515 | 57.5888 | 21.2068 | ------ | ------ | 2.6768 | ------ | ------ |
| 1000 | 8.7092 | 7.9643 | 68.9205 | 58.5042 | 19.1610 | 1825 | 0.01791 | 1.7540 | 817 | 0.01517 |
| 1100 | 8.7472 | 8.8371 | 69.7933 | 59.3360 | 17.4840 | 1663 | 0.01427 | 0.9961 | 745 | 0.01297 |
| 1200 | 8.7768 | 9.7133 | 70.6695 | 60.0984 | 16.0839 | 1528 | .01142 | .3623 | 684 | .01205 |
| 1300 | 8.8002 | 10.5921 | 71.5483 | 60.8019 | 14.8971 | 1413 | .00931 | −.1759 | 633 | .01076 |
| 1400 | 8.8190 | 11.4731 | 72.4293 | 61.4547 | 13.8785 | 1315 | .00733 | −.6388 | 589 | .00983 |
| 1500 | 8.8326 | 12.3557 | 73.3119 | 62.0636 | 12.9945 | 1229 | .00618 | −1.0413 | 551 | .00883 |
| 1600 | 8.8471 | 13.2397 | 74.1959 | 62.6341 | 12.2202 | 1154 | 0.00518 | −1.3945 | 518 | 0.00709 |
| 1700 | 8.8577 | 14.1249 | 75.0811 | 63.1708 | 11.5362 | 1087 | .00461 | −1.7072 | 488 | .00759 |
| 1800 | 8.8666 | 15.0111 | 75.9673 | 63.6774 | 10.9277 | 1028 | .00375 | −1.9859 | 462 | .00694 |
| 1900 | 8.8742 | 15.8982 | 76.8544 | 64.1570 | 10.3829 | 975 | .00330 | −2.2360 | 438 | .00680 |
| 2000 | 8.8807 | 16.7859 | 77.7421 | 64.6123 | 9.8921 | 927 | .00287 | −2.4618 | 417 | .00633 |
| 2100 | 8.8863 | 17.6742 | 78.6304 | 65.0457 | 9.4478 | 884 | 0.00238 | −2.6667 | 398 | 0.00579 |
| 2200 | 8.8912 | 18.5631 | 79.5193 | 65.4592 | 9.0436 | 844 | .00224 | −2.8534 | 381 | .00535 |
| 2300 | 8.8955 | 19.4525 | 80.4087 | 65.8546 | 8.6744 | 808 | .00193 | −3.0244 | 365 | .00512 |
| 2400 | 8.8993 | 20.3422 | 81.2984 | 66.2332 | 8.3358 | 775 | .00170 | −3.1816 | 350 | .00500 |
| 2500 | 8.9026 | 21.2323 | 82.1885 | 66.5966 | 8.0241 | 744 | .00165 | −3.3266 | 336 | .00497 |
| 2600 | 8.9056 | 22.1227 | 83.0789 | 66.9458 | 7.7368 | 716 | 0.00152 | −3.4606 | 324 | 0.00460 |
| 2700 | 8.9082 | 23.0134 | 83.9696 | 67.2819 | 7.4696 | 690 | .00117 | −3.5854 | 313 | .00431 |
| 2800 | 8.9106 | 23.1043 | 84.0605 | 67.6060 | 7.2220 | 606 | .00104 | −3.7015 | 302 | .00416 |
| 2900 | 8.9127 | 24.7955 | 85.7517 | 67.9187 | 6.9913 | 643 | .00107 | −3.8098 | 292 | .00397 |
| 3000 | 8.9146 | 25.6869 | 86.6431 | 68.2209 | 6.7759 | 622 | .00085 | −3.9111 | 283 | .00371 |
| 3100 | 8.9164 | 26.5784 | 87.5346 | 68.5132 | 6.5744 | 602 | 0.00088 | −4.0061 | 275 | .00340 |
| 3200 | 8.9180 | 27.4701 | 88.4263 | 68.7963 | 6.3854 | 584 | .00063 | −4.0955 | 266 | .00349 |
| 3300 | 8.9194 | 28.3620 | 89.3182 | 69.0708 | 6.2078 | 566 | .00063 | −4.1796 | 258 | .00352 |
| 3400 | 8.9209 | 29.2540 | 90.2102 | 69.3370 | 6.0407 | 550 | .00056 | −4.2590 | 251 | .00339 |
| 3500 | 8.9220 | 30.1462 | 91.1024 | 69.5956 | 5.8830 | 534 | .00057 | −4.3341 | 244 | .00322 |
| 3600 | 8.9231 | 31.0384 | 91.9946 | 69.8470 | 5.7341 | 520 | 0.00046 | −4.4051 | 238 | 0.00308 |
| 3700 | 8.9241 | 31.9308 | 92.8870 | 70.0915 | 5.5931 | 506 | .00034 | −4.4725 | 232 | .00295 |
| 3800 | 8.9250 | 32.8232 | 93.7794 | 70.3295 | 5.4596 | 492 | .00055 | −4.5365 | 226 | .00295 |
| 3900 | 8.9259 | 33.7158 | 94.6720 | 70.5614 | 5.3329 | 480 | .00040 | −4.5974 | 221 | .00275 |
| 4000 | 8.9267 | 34.6084 | 95.5646 | 70.7873 | 5.2125 | 468 | .00035 | −4.6554 | 215 | .00276 |
| 4100 | 8.9274 | 35.5011 | 96.4573 | 71.0078 | 5.0980 | 457 | .00039 | −4.7106 | 210 | .00280 |
| 4200 | 8.9281 | 36.3939 | 97.3501 | 71.2229 | 4.9888 | 446 | .00028 | −4.7634 | 206 | .00259 |
| 4300 | 8.9288 | 37.2867 | 98.2429 | 71.4330 | 4.8848 | 436 | .00021 | −4.8139 | 201 | .00262 |
| 4400 | 8.9294 | 38.1796 | 99.1358 | 71.6383 | 4.7855 | 426 | .00023 | −4.8622 | 196 | .00264 |
| 4500 | 8.9300 | 39.0726 | 100.0288 | 71.8390 | 4.6906 | 417 | .00025 | −4.9084 | 192 | .00256 |
| 4600 | 8.9305 | 39.9656 | 100.9218 | 72.0352 | 4.5997 | 407 | 0.00030 | −4.9527 | 188 | 0.00260 |
| 4700 | 8.9310 | 40.8587 | 101.8149 | 72.2273 | 4.5128 | 399 | .00028 | −4.9953 | 184 | .00247 |
| 4800 | 8.9315 | 41.7518 | 102.7080 | 72.4153 | 4.4294 | 391 | .00010 | −5.0361 | 181 | .00246 |
| 4900 | 8.9319 | 42.6450 | 103.6012 | 72.5995 | 4.3495 | 383 | .00020 | −5.0755 | 177 | .00240 |
| 5000 | 8.9323 | 43.5382 | 104.4944 | 72.7800 | 4.2727 | 375 | .00027 | −5.1133 | 174 | .00228 |
| 5100 | 8.9327 | 44.4315 | 105.3877 | 72.9568 | 4.1989 | 368 | 0.00013 | −5.1497 | 171 | 0.00222 |
| 5200 | 8.9331 | 45.3248 | 106.2810 | 73.1303 | 4.1280 | 361 | .00019 | −5.1848 | 168 | .00220 |
| 5300 | 8.9334 | 46.2181 | 107.1743 | 73.3005 | 4.0597 | 354 | .00014 | −5.2187 | 165 | .00214 |
| 5400 | 8.9337 | 47.1114 | 108.0676 | 73.4674 | 3.9940 | 348 | .00013 | −5.2514 | 161 | .00223 |
| 5500 | 8.9340 | 48,0048 | 108.9610 | 73.6314 | 3.9306 | 341 | .00021 | −5.2829 | 159 | .00221 |
| 5600 | 8.9343 | 48.8982 | 109.8544 | 73.7924 | 3.8695 | 335 | 0.00023 | −5.3135 | 156 | 0.00213 |
| 5700 | 8.9346 | 49.7917 | 110.7479 | 73.9505 | 3.8105 | 329 | .00018 | −5.3430 | 153 | .00222 |
| 5800 | 9.9349 | 50.6852 | 111.6414 | 74.1059 | 3.7536 | 324 | .00008 | −5.3716 | 150 | .00218 |
| 5900 | 8.8351 | 51.5787 | 112.5349 | 74.2586 | 3.6986 | 318 | .00020 | −5.3992 | 148 | .00213 |
| 6000 | 8.8353 | 52.4722 | 113.4284 | 74.4088 | 3.6454 | ------ | ------ | −5.4260 | ------ | ------ |

## TABLE XXIX—THERMODYNAMIC PROPERTIES OF H (GAS)

[Atomic weight, 1.008]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ |
|---|---|---|---|---|
| 0 | ---------- | 0 | 85.3285 | ---------- |
| 298.16 | 4.9680 | 1.4812 | 86.8097 | 27.3927 |
| 300 | 4.9080 | 1.4904 | 86.8189 | 27.4232 |
| 400 | 4.9680 | 1.9872 | 87.3157 | 28.8524 |
| 500 | 4.9680 | 2.4840 | 87.8125 | 29.9610 |
| 600 | 4.9680 | 2.9808 | 88.3093 | 30.8667 |
| 700 | 4.9680 | 3.4776 | 88.8061 | 31.6326 |
| 800 | 4.9680 | 3.9744 | 89.3029 | 32.2959 |
| 900 | 4.9680 | 4.4712 | 89.7997 | 32.8811 |
| 1000 | 4.9680 | 4.9680 | 90.2965 | 33.4045 |
| 1100 | 4.9680 | 5.4648 | 90.7933 | 33.8780 |
| 1200 | 4.9680 | 5.9616 | 91.2901 | 34.3103 |
| 1300 | 4.9680 | 6.4584 | 91.7869 | 34.7079 |
| 1400 | 4.9680 | 6.9552 | 92.2837 | 35.0761 |
| 1500 | 4.9680 | 7.4520 | 92.7805 | 35.4188 |
| 1600 | 4.9680 | 7.9488 | 93.2773 | 35.7395 |
| 1700 | 4.9680 | 8.4456 | 93.7741 | 36.0407 |
| 1800 | 4.9680 | 8.9424 | 94.2709 | 36.3246 |
| 1900 | 4.9680 | 9.4392 | 94.7677 | 36.5932 |
| 2000 | 4.9680 | 9.9360 | 95.2645 | 36.8480 |
| 2100 | 4.9680 | 10.4328 | 95.7613 | 37.0904 |
| 2200 | 4.9680 | 10.9296 | 96.2581 | 37.3215 |
| 2300 | 4.9680 | 11.4264 | 96.7549 | 37.5424 |
| 2400 | 4.9680 | 11.9232 | 97.2517 | 37.7538 |
| 2500 | 4.9680 | 12.4200 | 97.7485 | 37.9566 |
| 2600 | 4.9680 | 12.9168 | 98.2453 | 38.1515 |
| 2700 | 4.9680 | 13.4136 | 98.7421 | 38.3390 |
| 2800 | 4.9680 | 13.9104 | 99.2389 | 38.5196 |
| 2900 | 4.9680 | 14.4072 | 99.7357 | 38.6940 |
| 3000 | 4.9680 | 14.9040 | 100.2325 | 38.8624 |
| 3100 | 4.9680 | 15.4008 | 100.7293 | 39.0253 |
| 3200 | 4.9680 | 15.8976 | 101.2261 | 39.1830 |
| 3300 | 4.9680 | 16.3944 | 101.7229 | 39.3359 |
| 3400 | 4.9680 | 16.8912 | 102.2197 | 39.4842 |
| 3500 | 4.9680 | 17.3880 | 102.7165 | 39.6282 |
| 3600 | 4.9680 | 17.8848 | 103.2133 | 39.7681 |
| 3700 | 4.9680 | 18.3816 | 103.7101 | 39.9043 |
| 3800 | 4.9680 | 18.8784 | 104.2069 | 40.0368 |
| 3900 | 4.9680 | 19.3752 | 104.7037 | 40.1658 |
| 4000 | 4.9680 | 19.8720 | 105.2005 | 40.2916 |
| 4100 | 4.9680 | 20.3688 | 105.6973 | 40.4142 |
| 4200 | 4.9680 | 20.8656 | 106.1941 | 40.5340 |
| 4300 | 4.9680 | 21.3624 | 106.6909 | 40.6509 |
| 4400 | 4.9680 | 21.8592 | 107.1877 | 40.7651 |
| 4500 | 4.9680 | 22.3560 | 107.6845 | 40.8767 |
| 4600 | 4.9680 | 22.8528 | 108.1813 | 40.9859 |
| 4700 | 4.9680 | 23.3496 | 108.6781 | 41.0928 |
| 4800 | 4.9680 | 23.8464 | 109.1749 | 41.1973 |
| 4900 | 4.9680 | 24.3432 | 109.6717 | 41.2998 |
| 5000 | 4.9680 | 24.8400 | 110.1685 | 41.4002 |
| 5100 | 4.9680 | 25.3368 | 110.6653 | 41.4985 |
| 5200 | 4.9680 | 25.8336 | 111.1621 | 41.5950 |
| 5300 | 4.9680 | 26.3304 | 111.6589 | 41.6896 |
| 5400 | 4.9680 | 26.8272 | 112.1557 | 41.7825 |
| 5500 | 4.9680 | 27.3240 | 112.6525 | 41.8736 |
| 5600 | 4.9680 | 27.8208 | 113.1493 | 41.9632 |
| 5700 | 4.9680 | 28.3176 | 113.6461 | 42.0511 |
| 5800 | 4.9680 | 28.8144 | 114.1429 | 42.1375 |
| 5900 | 4.9680 | 29.3112 | 114.6397 | 42.2224 |
| 6000 | 4.9680 | 29.8080 | 115.1365 | 42.3059 |

## TABLE XXX—THERMODYNAMIC PROPERTIES OF $H_2$ (GAS)

[Molecular weight, 2.016]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{cal}{mole\ °K}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{kcal}{mole}\right)$ | $H_T^\circ$ $\left(\frac{kcal}{mole}\right)$ | $S_T^\circ$ $\left(\frac{cal}{mole\ °K}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ $a$ | $b$ | $\log K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ $c$ | $d$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | --- | 0 | 67.4169 | --- | --- | --- | --- | --- | --- | --- |
| 298.16 | 6.892 | 2.0238 | 69.4407 | 31.211 | 175.8297 | --- | --- | 71.2098 | --- | --- |
| 300 | 6.895 | 2.0365 | 69.4534 | 31.253 | 174.7610 | --- | --- | 70.7414 | --- | --- |
| 400 | 6.974 | 2.7310 | 70.1479 | 33.250 | 131.4465 | --- | --- | 51.7421 | --- | --- |
| 500 | 6.993 | 3.4295 | 70.8464 | 34.809 | 105.4544 | --- | --- | 40.3099 | --- | --- |
| 600 | 7.008 | 4.1286 | 71.5455 | 36.084 | 88.1261 | --- | --- | 32.6669 | --- | --- |
| 700 | 7.035 | 4.8315 | 72.2484 | 37.167 | 75.7454 | --- | --- | 27.1921 | --- | --- |
| 800 | 7.078 | 5.5374 | 72.9543 | 38.108 | 66.4582 | --- | --- | 23.0744 | --- | --- |
| 900 | 7.139 | 6.2480 | 73.6649 | 38.946 | 59.2322 | --- | --- | 19.8636 | --- | --- |
| 1000 | 7.219 | 6.9658 | 74.3827 | 39.7040 | 53.4478 | 5185 | 0.02306 | 17.2883 | 2291 | 0.03007 |
| 1100 | 7.310 | 7.6923 | 75.1092 | 40.3963 | 48.7111 | 4712 | 0.02453 | 15.1755 | 2087 | 0.02583 |
| 1200 | 7.407 | 8.4281 | 75.8450 | 41.0365 | 44.7599 | 4318 | .02556 | 13.4105 | 1916 | .02315 |
| 1300 | 7.509 | 9.1739 | 76.5908 | 41.6334 | 41.4128 | 3985 | .02637 | 11.9135 | 1772 | .02029 |
| 1400 | 7.615 | 9.9301 | 77.3470 | 42.1938 | 38.5400 | 3700 | .02653 | 10.6275 | 1648 | .01833 |
| 1500 | 7.7202 | 10.6969 | 78.1138 | 42.7227 | 36.0468 | 3454 | .02605 | 9.5105 | 1541 | .01628 |
| 1600 | 7.8232 | 11.4740 | 78.8909 | 43.2243 | 33.8620 | 3240 | 0.02502 | 8.5311 | 1447 | 0.01472 |
| 1700 | 7.9229 | 12.2613 | 79.6782 | 43.7016 | 31.9311 | 3051 | .02400 | 7.6652 | 1364 | .01332 |
| 1800 | 8.0185 | 13.0584 | 80.4753 | 44.1571 | 30.2121 | 2884 | .02261 | 6.8941 | 1291 | .01173 |
| 1900 | 8.1093 | 13.8648 | 81.2817 | 44.5931 | 28.6716 | 2734 | .02170 | 6.2029 | 1225 | .01060 |
| 2000 | 8.1949 | 14.6800 | 82.0969 | 45.0112 | 27.2829 | 2600 | .02031 | 5.5798 | 1166 | .00946 |
| 2100 | 8.2762 | 15.5036 | 82.9205 | 45.4130 | 26.0245 | 2478 | 0.01954 | 5.0151 | 1112 | 0.00865 |
| 2200 | 8.3537 | 16.3351 | 83.7520 | 45.7998 | 24.8786 | 2367 | .01867 | 4.5010 | 1063 | .00793 |
| 2300 | 8.4274 | 17.1741 | 84.5910 | 46.1728 | 23.8308 | 2267 | .01752 | 4.0309 | 1018 | .00733 |
| 2400 | 8.4977 | 18.0204 | 85.4373 | 46.5329 | 22.8687 | 2174 | .01690 | 3.5904 | 978 | .00640 |
| 2500 | 8.5647 | 18.8735 | 86.2904 | 46.8812 | 21.9822 | 2089 | .01604 | 3.2018 | 940 | .00586 |
| 2600 | 8.6286 | 19.7331 | 87.1500 | 47.2183 | 21.1627 | 2011 | 0.01519 | 2.8344 | 905 | 0.00541 |
| 2700 | 8.6896 | 20.5991 | 88.0160 | 47.5451 | 20.4027 | 1938 | .01466 | 2.4938 | 873 | .00481 |
| 2800 | 8.7479 | 21.4709 | 88.8878 | 47.8622 | 19.6959 | 1870 | .01417 | 2.1772 | 843 | .00441 |
| 2900 | 8.8042 | 22.3485 | 89.7654 | 48.1702 | 19.0369 | 1807 | .01377 | 1.8821 | 815 | .00403 |
| 3000 | 8.8587 | 23.2317 | 90.6486 | 48.4696 | 18.4208 | 1748 | .01323 | 1.6064 | 789 | .00368 |
| 3100 | 8.9118 | 24.1202 | 91.5371 | 48.7609 | 17.8437 | 1693 | 0.01294 | 1.3482 | 764 | 0.00355 |
| 3200 | 8.9636 | 25.0140 | 92.4309 | 49.0447 | 17.3017 | 1640 | .01263 | 1.1059 | 741 | .00325 |
| 3300 | 9.0143 | 25.9129 | 93.3298 | 49.3213 | 16.7919 | 1591 | .01266 | .8781 | 719 | .00313 |
| 3400 | 9.0639 | 26.8168 | 94.2337 | 49.5911 | 16.3113 | 1546 | .01219 | .6635 | 699 | .00279 |
| 3500 | 9.1125 | 27.7256 | 95.1425 | 49.8545 | 15.8574 | 1502 | .01208 | .4610 | 680 | .00241 |
| 3600 | 9.1602 | 28.6392 | 96.0561 | 50.1119 | 15.4281 | 1461 | 0.01184 | 0.2697 | 662 | 0.00228 |
| 3700 | 9.2070 | 29.5576 | 96.9745 | 50.3635 | 15.0214 | 1423 | .01153 | .0885 | 644 | .00223 |
| 3800 | 9.2529 | 30.4806 | 97.8975 | 50.6097 | 14.6354 | 1386 | .01132 | −.0832 | 628 | .00197 |
| 3900 | 9.2979 | 31.4081 | 98.8250 | 50.8506 | 14.2687 | 1351 | .01125 | −.2462 | 613 | .00175 |
| 4000 | 9.3421 | 32.3401 | 99.7570 | 51.0866 | 13.9197 | 1318 | .01104 | −.4012 | 598 | .00165 |
| 4100 | 9.3856 | 33.2765 | 100.6934 | 51.3178 | 13.5872 | 1287 | 0.01067 | −0.5487 | 584 | 0.00145 |
| 4200 | 9.4283 | 34.2172 | 101.6341 | 51.5445 | 13.2701 | 1257 | .01057 | −.6892 | 571 | .00131 |
| 4300 | 9.4704 | 35.1621 | 102.5790 | 51.7668 | 12.9672 | 1229 | .01038 | −.8233 | 558 | .00118 |
| 4400 | 9.5118 | 36.1113 | 103.5282 | 51.9850 | 12.6775 | 1201 | .01031 | −.9513 | 546 | .00097 |
| 4500 | 9.5526 | 37.0645 | 104.4814 | 52.1992 | 12.4003 | 1175 | .01017 | −1.0736 | 535 | .00080 |
| 4600 | 9.5928 | 38.0217 | 105.4386 | 52.4096 | 12.1347 | 1150 | 0.01002 | −1.1907 | 524 | 0.00071 |
| 4700 | 9.6324 | 38.9830 | 106.3999 | 52.6164 | 11.8800 | 1127 | .00971 | −1.3029 | 514 | .00042 |
| 4800 | 9.6714 | 39.9482 | 107.3651 | 52.8196 | 11.6355 | 1104 | .00969 | −1.4104 | 503 | .00045 |
| 4900 | 9.7099 | 40.9173 | 108.3342 | 53.0194 | 11.4005 | 1082 | .00950 | −1.5135 | 494 | .00030 |
| 5000 | 9.7479 | 41.8901 | 109.3070 | 53.2159 | 11.1746 | 1061 | .00936 | −1.6126 | 484 | .00020 |
| 5100 | 9.7853 | 42.8668 | 110.2837 | 53.4093 | 10.9572 | 1041 | 0.00931 | −1.7077 | 475 | 0.00015 |
| 5200 | 9.8222 | 43.8472 | 111.2641 | 53.5997 | 10.7477 | 1021 | .00916 | −1.7992 | 466 | .00018 |
| 5300 | 9.8586 | 44.8312 | 112.2481 | 53.7871 | 10.5459 | 1003 | .00906 | −1.8873 | 458 | −.00001 |
| 5400 | 9.8945 | 45.8189 | 113.2358 | 53.9717 | 10.3511 | 985 | .00891 | −1.9721 | 450 | −.00002 |
| 5500 | 9.9299 | 46.8101 | 114.2270 | 54.1536 | 10.1631 | 967 | .00882 | −2.0539 | 442 | −.00013 |
| 5600 | 9.9649 | 47.8048 | 115.2217 | 54.3328 | 9.9816 | 951 | 0.00876 | −2.1327 | 434 | −0.00014 |
| 5700 | 9.9994 | 48.8031 | 116.2200 | 54.5095 | 9.8060 | 934 | .00867 | −2.2087 | 427 | −.00012 |
| 5800 | 10.0334 | 49.8047 | 117.2216 | 54.6837 | 9.6363 | 919 | .00854 | −2.2822 | 420 | −.00029 |
| 5900 | 10.0670 | 50.8097 | 118.2266 | 54.8555 | 9.4720 | 904 | .00843 | −2.3531 | 413 | −.00033 |
| 6000 | 10.1001 | 51.8181 | 119.2350 | 55.0250 | 9.3129 | --- | --- | −2.4216 | --- | --- |

## TABLE XXXI—THERMODYNAMIC PROPERTIES OF HCl (GAS)

[Molecular weight, 36.465]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $\frac{\Delta H^\circ}{RT}$ | $\delta\left(\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$: $a$ | $b$ | $\log K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$: $c$ | $d$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | ---------- | 0 | 15.5926 | ---------- | ---------- | -------- | ---------- | ---------- | -------- | ---------- |
| 298.16 | 6.96 | 2.0648 | 17.6574 | 44.617 | 174.1180 | -------- | ---------- | 70.7596 | -------- | ---------- |
| 300 | 6.96 | 2.0778 | 17.6704 | 44.661 | 173.0598 | -------- | ---------- | 70.2960 | -------- | ---------- |
| 400 | 6.97 | 2.7740 | 18.3666 | 46.656 | 130.2113 | -------- | ---------- | 51.4775 | -------- | ---------- |
| 500 | 7.00 | 3.4730 | 19.0656 | 48.224 | 104.5100 | -------- | ---------- | 40.1522 | -------- | ---------- |
| 600 | 7.07 | 4.1766 | 19.7692 | 49.506 | 87.3747 | -------- | ---------- | 32.5758 | -------- | ---------- |
| 700 | 7.17 | 4.8881 | 20.4807 | 50.603 | 75.1291 | -------- | ---------- | 27.1468 | -------- | ---------- |
| 800 | 7.29 | 5.6112 | 21.2038 | 51.568 | 65.9356 | -------- | ---------- | 23.0623 | -------- | ---------- |
| 900 | 7.42 | 6.3468 | 21.9394 | 52.434 | 58.7762 | -------- | ---------- | 19.8761 | -------- | ---------- |
| 1000 | 7.554 | 7.0950 | 22.6876 | 53.2220 | 53.0404 | 5124 | 0.04282 | 17.3201 | 2274 | 0.02943 |
| 1100 | 7.690 | 7.8572 | 23.4498 | 53.9484 | 48.3394 | 4661 | 0.04023 | 15.2234 | 2071 | 0.02567 |
| 1200 | 7.819 | 8.6326 | 24.2252 | 54.6230 | 44.4150 | 4277 | .03660 | 13.4719 | 1903 | .02145 |
| 1300 | 7.938 | 9.4205 | 25.0131 | 55.2536 | 41.0884 | 3952 | .03354 | 11.9866 | 1760 | .01876 |
| 1400 | 8.046 | 10.2197 | 25.8123 | 55.8458 | 38.2320 | 3676 | .02903 | 10.7107 | 1637 | .01667 |
| 1500 | 8.140 | 11.0290 | 26.6216 | 56.4041 | 35.7573 | 3437 | .02498 | 9.6027 | 1530 | .01505 |
| 1600 | 8.221 | 11.8470 | 27.4396 | 56.9320 | 33.5792 | 3227 | 0.02197 | 8.6314 | 1437 | 0.01331 |
| 1700 | 8.292 | 12.6727 | 28.2653 | 57.4325 | 31.6590 | 3040 | .02031 | 7.7728 | 1355 | .01172 |
| 1800 | 8.358 | 13.5052 | 29.0978 | 57.9084 | 29.9498 | 2871 | .02045 | 7.0083 | 1282 | .01036 |
| 1900 | 8.426 | 14.3444 | 29.9370 | 58.3621 | 28.4183 | 2723 | .01870 | 6.3232 | 1216 | .00960 |
| 2000 | 8.488 | 15.1901 | 30.7827 | 58.7958 | 27.0381 | 2590 | .01717 | 5.7056 | 1157 | .00855 |
| 2100 | 8.545 | 16.0417 | 31.6343 | 59.2114 | 25.7876 | 2471 | 0.01502 | 5.1461 | 1103 | 0.00804 |
| 2200 | 8.595 | 16.8987 | 32.4913 | 59.6100 | 24.6494 | 2361 | .01398 | 4.6367 | 1055 | .00710 |
| 2300 | 8.643 | 17.7606 | 33.3532 | 59.9982 | 23.6089 | 2262 | .01240 | 4.1709 | 1010 | .00667 |
| 2400 | 8.685 | 18.6270 | 34.2196 | 60.3619 | 22.6540 | 2169 | .01190 | 3.7434 | 969 | .00620 |
| 2500 | 8.726 | 19.4976 | 35.0902 | 60.7172 | 21.7745 | 2086 | .01039 | 3.3496 | 931 | .00582 |
| 2600 | 8.762 | 20.3720 | 35.9646 | 61.0602 | 20.9618 | 2007 | 0.00997 | 2.9857 | 896 | 0.00545 |
| 2700 | 8.796 | 21.2499 | 36.8425 | 61.3915 | 20.2085 | 1934 | .00939 | 2.6484 | 864 | .00513 |
| 2800 | 8.829 | 22.1311 | 37.7237 | 61.7120 | 19.5084 | 1868 | .00846 | 2.3347 | 834 | .00471 |
| 2900 | 8.858 | 23.0155 | 38.6081 | 62.0223 | 18.8558 | 1805 | .00783 | 2.0424 | 806 | .00443 |
| 3000 | 8.885 | 23.9026 | 39.4952 | 62.3231 | 18.2463 | 1745 | .00780 | 1.7693 | 780 | .00409 |
| 3100 | 8.912 | 24.7925 | 40.3851 | 62.6148 | 17.6756 | 1691 | 0.00706 | 1.5136 | 756 | 0.00375 |
| 3200 | 8.937 | 25.6849 | 41.2775 | 62.8982 | 17.1401 | 1639 | .00683 | 1.2736 | 733 | .00358 |
| 3300 | 8.961 | 26.5798 | 42.1724 | 63.1736 | 16.6366 | 1591 | .00626 | 1.0479 | 711 | .00348 |
| 3400 | 8.983 | 27.4770 | 43.0696 | 63.4414 | 16.1624 | 1545 | .00607 | .8353 | 691 | .00327 |
| 3500 | 9.004 | 28.3764 | 43.9690 | 63.7021 | 15.7149 | 1502 | .00578 | .6346 | 671 | .00321 |
| 3600 | 9.024 | 29.2778 | 44.8704 | 63.9560 | 15.2919 | 1462 | 0.00527 | 0.4450 | 654 | 0.00284 |
| 3700 | 9.043 | 30.1811 | 45.7737 | 64.2035 | 14.8915 | 1421 | .00565 | .2654 | 636 | .00283 |
| 3800 | 9.063 | 31.0864 | 46.6790 | 64.4450 | 14.5119 | 1386 | .00502 | .0952 | 620 | .00273 |
| 3900 | 9.081 | 31.9936 | 47.5862 | 64.6806 | 14.1515 | 1352 | .00460 | −.0665 | 604 | .00270 |
| 4000 | 9.098 | 32.8026 | 48.4952 | 64.9108 | 13.8089 | 1318 | .00474 | −.2202 | 590 | .00250 |
| 4100 | 9.115 | 33.8132 | 49.4058 | 65.1356 | 13.4827 | 1287 | 0.00437 | −0.3666 | 576 | 0.00226 |
| 4200 | 9.131 | 34.7255 | 50.3181 | 65.3554 | 13.1719 | 1256 | .00451 | −.5060 | 563 | .00217 |
| 4300 | 9.147 | 35.6394 | 51.2320 | 65.5705 | 12.8753 | 1228 | .00421 | −.6391 | 551 | .00197 |
| 4400 | 9.162 | 36.5549 | 52.1475 | 65.7810 | 12.5920 | 1202 | .00379 | −.7663 | 538 | .00194 |
| 4500 | 9.176 | 37.4718 | 53.0644 | 65.9870 | 12.3211 | 1174 | .00408 | −.8878 | 527 | .00183 |
| 4600 | 9.191 | 38.3901 | 53.9627 | 66.1888 | 12.0618 | 1150 | 0.00372 | −1.0042 | 516 | 0.00171 |
| 4700 | 9.205 | 39.3099 | 54.9025 | 66.3867 | 11.8134 | 1127 | .00341 | −1.1157 | 505 | .00169 |
| 4800 | 9.218 | 40.2311 | 55.8237 | 66.5806 | 11.5752 | 1102 | .00330 | −1.2226 | 495 | .00158 |
| 4900 | 9.232 | 41.1536 | 56.7462 | 66.7708 | 11.3465 | 1081 | .00340 | −1.3252 | 485 | .00160 |
| 5000 | 9.245 | 42.0774 | 57.6700 | 66.9574 | 11.1269 | 1060 | .00336 | −1.4238 | 476 | .00147 |
| 5100 | 9.257 | 43.0025 | 58.5951 | 67.1406 | 10.9157 | 1038 | 0.00348 | −1.5186 | 467 | 0.00139 |
| 5200 | 9.270 | 43.9289 | 59.5215 | 67.3205 | 10.7126 | 1020 | .00325 | −1.6098 | 458 | .00138 |
| 5300 | 9.282 | 44.8565 | 60.4491 | 67.4972 | 10.5169 | 1001 | .00313 | −1.6976 | 449 | .00145 |
| 5400 | 9.294 | 45.7853 | 61.3779 | 67.6708 | 10.3284 | 982 | .00325 | −1.7822 | 441 | .00142 |
| 5500 | 9.306 | 46.7153 | 62.3079 | 67.8415 | 10.1466 | 964 | .00316 | −1.8638 | 433 | .00138 |
| 5600 | 9.318 | 47.6465 | 63.2391 | 68.0093 | 9.9713 | 947 | 0.00326 | −1.9425 | 426 | 0.00126 |
| 5700 | 9.330 | 48.5789 | 64.1715 | 68.1743 | 9.8019 | 930 | .00326 | −2.0185 | 419 | .00116 |
| 5800 | 9.342 | 49.5125 | 65.1051 | 68.3367 | 9.6383 | 914 | .00328 | −2.0919 | 412 | .00117 |
| 5900 | 9.354 | 50.4473 | 66.0399 | 68.4965 | 9.4801 | 900 | .00300 | −2.1629 | 405 | .00110 |
| 6000 | 9.365 | 51.3832 | 66.9758 | 68.6538 | 9.3271 | -------- | ---------- | −2.2315 | -------- | ---------- |

## TABLE XXXII—THERMODYNAMIC PROPERTIES OF HF (GAS)

[Molecular weight, 20.008]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | ---------- | 0 | 0 | 0 | ---------- | -------- | ---------- | ---------- | -------- | ---------- |
| 298.16 | 6.9615 | 2.0553 | 2.0553 | 41.5114 | 227.1579 | -------- | ---------- | 93.4523 | -------- | ---------- |
| 300 | 6.9615 | 2.0681 | 2.0681 | 41.5542 | 225.7754 | -------- | ---------- | 92.8472 | -------- | ---------- |
| 400 | 6.9652 | 2.7645 | 2.7645 | 43.5575 | 169.7599 | -------- | ---------- | 68.3058 | -------- | ---------- |
| 500 | 6.9715 | 3.4613 | 3.4613 | 45.1124 | 136.1421 | -------- | ---------- | 53.5438 | -------- | ---------- |
| 600 | 6.9858 | 4.1592 | 4.1592 | 46.3848 | 113.7233 | -------- | ---------- | 43.6784 | -------- | ---------- |
| 700 | 7.0150 | 4.8592 | 4.8592 | 47.4639 | 97.7043 | -------- | ---------- | 36.6149 | -------- | ---------- |
| 800 | 7.0627 | 5.5631 | 5.5631 | 48.4098 | 85.6849 | -------- | ---------- | 31.3051 | -------- | ---------- |
| 900 | 7.1290 | 6.2727 | 6.2727 | 49.2396 | 76.3316 | -------- | ---------- | 27.1660 | -------- | ---------- |
| 1000 | 7.2108 | 6.9897 | 6.9897 | 49.9950 | 68.8439 | 6714 | 0.02746 | 23.8476 | 2959 | 0.03070 |
| 1100 | 7.3038 | 7.7154 | 7.7154 | 50.0866 | 62.7128 | 6103 | 0.02817 | 21.1269 | 2694 | 0.02690 |
| 1200 | 7.4035 | 8.4508 | 8.4508 | 51.3264 | 57.5088 | 5594 | .02852 | 18.8550 | 2473 | .02359 |
| 1300 | 7.5059 | 9.1962 | 9.1962 | 51.9231 | 53.2672 | 5164 | .02823 | 16.9291 | 2257 | .02033 |
| 1400 | 7.6084 | 9.9520 | 9.9520 | 52.4831 | 49.5504 | 4797 | .02700 | 15.2752 | 2126 | .01847 |
| 1500 | 7.7084 | 10.7178 | 10.7178 | 53.0114 | 46.3254 | 4479 | .02573 | 13.8394 | 1987 | .01653 |
| 1600 | 7.8048 | 11.4935 | 11.4935 | 53.5120 | 43.5003 | 4201 | 0.02452 | 12.5810 | 1866 | 0.01455 |
| 1700 | 7.8967 | 12.2785 | 12.2785 | 53.9879 | 41.0046 | 3956 | .02332 | 11.4688 | 1758 | .01333 |
| 1800 | 7.9836 | 13.0726 | 13.0726 | 54.4417 | 38.7835 | 3739 | .02161 | 10.4788 | 1662 | .01236 |
| 1900 | 8.0657 | 13.8750 | 13.8750 | 54.8756 | 36.7940 | 3545 | .02030 | 9.5917 | 1577 | .01100 |
| 2000 | 8.1427 | 14.6854 | 14.6854 | 55.2912 | 35.0012 | 3370 | .01904 | 8.7922 | 1500 | .01011 |
| 2100 | 8.2150 | 15.5033 | 15.5033 | 55.6903 | 33.3774 | 3212 | 0.01790 | 8.0678 | 1430 | 0.00920 |
| 2200 | 8.2828 | 16.3282 | 16.3282 | 56.0740 | 31.8995 | 3069 | .01655 | 7.4086 | 1367 | .00835 |
| 2300 | 8.3464 | 17.1597 | 17.1597 | 56.4436 | 30.5486 | 2938 | .01543 | 6.8059 | 1309 | .00768 |
| 2400 | 8.4061 | 17.9973 | 17.9973 | 56.8001 | 29.3090 | 2818 | .01450 | 6.2528 | 1256 | .00710 |
| 2500 | 8.4623 | 18.8407 | 18.8407 | 57.1444 | 28.1673 | 2707 | .01385 | 5.7433 | 1206 | .00685 |
| 2600 | 8.5152 | 19.6896 | 19.6896 | 57.4773 | 27.1123 | 2605 | 0.01289 | 5.2726 | 1161 | 0.00630 |
| 2700 | 8.5650 | 20.5436 | 20.5436 | 57.7996 | 26.1346 | 2510 | .01247 | 4.8363 | 1119 | .00596 |
| 2800 | 8.6124 | 21.4025 | 21.4025 | 58.1119 | 25.2257 | 2423 | .01148 | 4.4307 | 1080 | .00549 |
| 2900 | 8.6572 | 22.2660 | 22.2660 | 58.4149 | 24.3787 | 2341 | .01087 | 4.0528 | 1044 | .00510 |
| 3000 | 8.7000 | 23.1338 | 23.1338 | 58.7091 | 23.5675 | 2264 | .01058 | 3.6997 | 1010 | .00479 |
| 3100 | 8.7408 | 24.0059 | 24.0059 | 58.9951 | 22.8466 | 2193 | 0.00999 | 3.3691 | 979 | 0.00426 |
| 3200 | 8.7797 | 24.8819 | 24.8519 | 59.2732 | 22.1513 | 2126 | .00946 | 3.0589 | 949 | .00402 |
| 3300 | 8.8169 | 25.7617 | 25.7617 | 59.5439 | 21.4976 | 2062 | .00933 | 2.7673 | 921 | .00382 |
| 3400 | 8.8527 | 26.6452 | 26.6452 | 59.8077 | 20.8818 | 2003 | .00881 | 2.4926 | 895 | .00349 |
| 3500 | 8.8872 | 27.5322 | 27.5322 | 60.0648 | 20.3007 | 1947 | .00847 | 2.2334 | 870 | .00333 |
| 3600 | 8.9205 | 28.4226 | 28.4226 | 60.3156 | 19.7514 | 1894 | 0.00821 | 1.9884 | 847 | 0.00308 |
| 3700 | 8.9528 | 29.3162 | 29.3162 | 60.5605 | 19.2318 | 1843 | .00820 | 1.7564 | 824 | .00296 |
| 3800 | 8.9842 | 30.2131 | 30.2131 | 60.7996 | 18.7381 | 1795 | .00794 | 1.5366 | 804 | .00265 |
| 3900 | 9.0151 | 31.1130 | 31.1130 | 61.0334 | 18.2699 | 1750 | .00780 | 1.3278 | 784 | .00240 |
| 4000 | 9.0453 | 32.0161 | 32.0161 | 61.2620 | 17.8246 | 1707 | .00756 | 1.1294 | 765 | .00231 |
| 4100 | 9.0750 | 32.9221 | 32.9221 | 61.4858 | 17.4007 | 1666 | 0.00733 | 0.9405 | 746 | 0.00228 |
| 4200 | 9.1043 | 33.8310 | 33.8310 | 61.7048 | 16.9967 | 1626 | .00756 | .7606 | 730 | .00203 |
| 4300 | 9.1336 | 34.7429 | 34.7429 | 61.9194 | 16.6111 | 1588 | .00759 | .5888 | 713 | .00195 |
| 4400 | 9.1631 | 35.6578 | 35.6578 | 62.1297 | 16.2426 | 1551 | .00773 | .4248 | 697 | .00191 |
| 4500 | 9.1936 | 36.5756 | 36.5756 | 62.3359 | 15.8902 | 1513 | .00849 | .2680 | 682 | .00174 |
| 4600 | 9.2271 | 37.4966 | 37.4966 | 62.5384 | 15.5528 | 1479 | 0.00872 | 0.1180 | 668 | 0.00167 |
| 4700 | 9.2623 | 38.4211 | 38.4211 | 62.7372 | 15.2294 | 1446 | .00915 | −.0258 | 654 | .00155 |
| 4800 | 9.2978 | 39.3491 | 39.3491 | 62.9326 | 14.9190 | 1416 | .00902 | −.1636 | 641 | .00138 |
| 4900 | 9.3335 | 40.2807 | 40.2807 | 63.1246 | 14.6210 | 1387 | .00910 | −.2968 | 629 | .00130 |
| 5000 | 9.3690 | 41.2158 | 41.2158 | 63.3136 | 14.3345 | 1360 | .00898 | −.4229 | 616 | .00132 |
| 5100 | 9.4040 | 42.1545 | 42.1545 | 63.4994 | 14.0589 | 1334 | 0.00876 | −0.5450 | 604 | 0.00125 |
| 5200 | 9.4386 | 43.0966 | 43.0966 | 63.6824 | 13.7936 | 1309 | .00872 | −.6624 | 592 | .00130 |
| 5300 | 9.4726 | 44.0422 | 44.0422 | 63.8625 | 13.5379 | 1285 | .00844 | −.7754 | 582 | .00112 |
| 5400 | 9.5061 | 44.9911 | 44.9911 | 64.0399 | 13.2915 | 1262 | .00845 | −.8843 | 571 | .00118 |
| 5500 | 9.5391 | 45.9434 | 45.9434 | 64.2146 | 13.0536 | 1240 | .00817 | −.9893 | 561 | .00112 |
| 5600 | 9.5718 | 46.8989 | 46.8989 | 64.3868 | 12.8240 | 1218 | 0.00822 | −1.0906 | 551 | 0.00103 |
| 5700 | 9.6040 | 47.8577 | 47.8577 | 64.5565 | 12.6021 | 1198 | .00795 | −1.1883 | 541 | .00102 |
| 5800 | 9.6358 | 48.8197 | 48.8197 | 64.7238 | 12.3876 | 1177 | .00801 | −1.2826 | 532 | .00103 |
| 5900 | 9.6673 | 49.7848 | 49.7848 | 64.8888 | 12.1801 | 1158 | .00780 | −1.3738 | 524 | .00097 |
| 6000 | 9.6986 | 50.7531 | 50.7531 | 65.0515 | 11.9793 | -------- | ---------- | −1.4621 | -------- | ---------- |

## TABLE XXXIII—THERMODYNAMIC PROPERTIES OF $H_2O$ (GAS)

[Molecular weight, 18.016]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | ---------- | 0 | 11.3311 | ---------- | ---------- | -------- | ---------- | ---------- | -------- | ---------- |
| 298.16 | 8.025 | 2.3677 | 13.6988 | 45.106 | 373.2200 | -------- | ---------- | 151.5648 | -------- | ---------- |
| 300 | 8.026 | 2.3820 | 13.7131 | 45.154 | 370.9541 | -------- | ---------- | 150.5708 | -------- | ---------- |
| 400 | 8.185 | 3.1940 | 14.5251 | 47.490 | 279.0956 | -------- | ---------- | 110.2372 | -------- | ---------- |
| 500 | 8.415 | 4.0255 | 15.3566 | 49.344 | 223.9534 | -------- | ---------- | 85.9609 | -------- | ---------- |
| 600 | 8.677 | 4.8822 | 16.2133 | 50.903 | 187.1673 | -------- | ---------- | 69.7280 | -------- | ---------- |
| 700 | 8.959 | 5.7715 | 17.1026 | 52.269 | 160.8663 | -------- | ---------- | 58.0996 | -------- | ---------- |
| 800 | 9.254 | 6.6896 | 18.0207 | 53.490 | 141.1213 | -------- | ---------- | 49.3548 | -------- | ---------- |
| 900 | 9.559 | 7.6347 | 18.9658 | 54.599 | 125.7485 | -------- | ---------- | 42.5361 | -------- | ---------- |
| 1000 | 9.861 | 8.6080 | 19.9391 | 55.6180 | 113.4355 | 11,015 | 0.07316 | 37.0674 | 4875 | 0.05158 |
| 1100 | 10.145 | 9.6063 | 20.9394 | 56.5712 | 103.3487 | 10,019 | 0.06833 | 32.5840 | 4439 | 0.04493 |
| 1200 | 10.413 | 10.6362 | 21.9673 | 57.4654 | 94.9312 | 9,188 | .06491 | 28.8399 | 4076 | .03902 |
| 1300 | 10.668 | 11.6902 | 23.0213 | 58.3090 | 87.7986 | 8,486 | .06137 | 25.6655 | 3768 | .03457 |
| 1400 | 10.909 | 12.7691 | 24.1002 | 59.1084 | 81.6758 | 7,886 | .05696 | 22.9395 | 3505 | .03013 |
| 1500 | 11.134 | 13.8712 | 25.2023 | 59.8687 | 76.3615 | 7,366 | .05315 | 20.5727 | 3276 | .02690 |
| 1600 | 11.343 | 14.9951 | 26.3262 | 60.5939 | 71.7046 | 6,913 | 0.04853 | 18.4983 | 3075 | 0.02428 |
| 1700 | 11.534 | 16.1389 | 27.4700 | 61.2873 | 67.5896 | 6,514 | .04401 | 16.6652 | 2898 | .02200 |
| 1800 | 11.708 | 17.3010 | 28.6321 | 61.9515 | 63.9267 | 6,160 | .03959 | 15.0332 | 2741 | .01957 |
| 1900 | 11.865 | 18.4797 | 29.8108 | 62.5887 | 60.6450 | 5,843 | .03590 | 13.5710 | 2600 | .01770 |
| 2000 | 12.008 | 19.6733 | 31.0044 | 63.2010 | 57.6876 | 5,557 | .03271 | 12.2533 | 2474 | .01570 |
| 2100 | 12.138 | 20.8806 | 32.2117 | 63.7900 | 55.0087 | 5,299 | 0.02966 | 11.0595 | 2359 | 0.01423 |
| 2200 | 12.256 | 22.1003 | 33.4314 | 64.3574 | 52.5704 | 5,064 | .02686 | 9.9730 | 2255 | .01277 |
| 2300 | 12.364 | 23.3313 | 34.6624 | 64.9045 | 50.3418 | 4,849 | .02468 | 8.9798 | 2160 | .01150 |
| 2400 | 12.463 | 24.5727 | 35.9038 | 65.4328 | 48.2967 | 4,653 | .02220 | 8.0688 | 2072 | .01060 |
| 2500 | 12.554 | 25.8235 | 37.1546 | 65.9434 | 46.4133 | 4,471 | .02049 | 7.2259 | 1991 | .00993 |
| 2600 | 12.638 | 27.0831 | 38.4142 | 66.4374 | 44.6732 | 4,304 | 0.01863 | 6.4532 | 1916 | 0.00927 |
| 2700 | 12.715 | 28.3508 | 39.6819 | 66.9159 | 43.0605 | 4,149 | .01691 | 5.7343 | 1846 | .00896 |
| 2800 | 12.786 | 29.6258 | 40.9569 | 67.3796 | 41.5618 | 4,005 | .01547 | 5.0661 | 1781 | .00856 |
| 2900 | 12.852 | 30.9077 | 42.2388 | 67.8294 | 40.1653 | 3,871 | .01407 | 4.4434 | 1721 | .00803 |
| 3000 | 12.913 | 32.1960 | 43.5271 | 68.2661 | 38.8609 | 3,747 | .01239 | 3.8617 | 1666 | .00728 |
| 3100 | 12.968 | 33.4900 | 44.8211 | 68.6904 | 37.6398 | 3,630 | 0.01113 | 3.3170 | 1613 | 0.00694 |
| 3200 | 13.018 | 34.7893 | 46.1204 | 69.1029 | 36.4943 | 3,520 | .00993 | 2.8060 | 1564 | .00656 |
| 3300 | 13.064 | 36.0934 | 47.4245 | 69.5042 | 35.4177 | 3,417 | .00890 | 2.3255 | 1517 | .00642 |
| 3400 | 13.107 | 37.4020 | 48.7331 | 69.8949 | 34.4038 | 3,320 | .00793 | 1.8729 | 1473 | .00624 |
| 3500 | 13.147 | 38.7147 | 50.0458 | 70.2754 | 33.4473 | 3,228 | .00703 | 1.4458 | 1431 | .00610 |
| 3600 | 13.184 | 40.0312 | 51.3623 | 70.6463 | 32.5436 | 3,142 | 0.00601 | 1.0422 | 1392 | 0.00588 |
| 3700 | 13.218 | 41.3513 | 52.6824 | 71.0060 | 31.6884 | 3,059 | .00550 | .6601 | 1355 | .00572 |
| 3800 | 13.250 | 42.6747 | 54.0058 | 71.3609 | 30.8779 | 2,981 | .00484 | .2978 | 1320 | .00554 |
| 3900 | 13.280 | 44.0012 | 55.3323 | 71.7054 | 30.1087 | 2,907 | .00425 | −.0462 | 1287 | .00525 |
| 4000 | 13.308 | 45.3306 | 56.6617 | 72.0420 | 29.3777 | 2,836 | .00379 | −.3732 | 1255 | .00520 |
| 4100 | 13.334 | 46.6627 | 57.9938 | 72.3710 | 28.6522 | 2,769 | 0.00321 | −0.6845 | 1266 | 0.00480 |
| 4200 | 13.358 | 47.9973 | 59.3284 | 72.6926 | 28.0197 | 2,705 | .00283 | −.9812 | 1196 | .00450 |
| 4300 | 13.381 | 49.3343 | 60.6654 | 73.0071 | 27.3878 | 2,643 | .00262 | −1.2643 | 1170 | .00449 |
| 4400 | 13.403 | 50.6735 | 62.0046 | 73.3150 | 26.7845 | 2,584 | .00238 | −1.5347 | 1144 | .00438 |
| 4500 | 13.424 | 52.0148 | 63.3459 | 73.6164 | 26.2079 | 2,528 | .00204 | −1.7933 | 1119 | .00434 |
| 4600 | 13.444 | 53.3582 | 64.6893 | 73.9117 | 25.6563 | 2,473 | 0.00203 | −2.0409 | 1095 | 0.00412 |
| 4700 | 13.464 | 54.7036 | 66.0347 | 74.2011 | 25.1281 | 2,421 | .00198 | −2.2780 | 1073 | .00396 |
| 4800 | 13.483 | 56.0510 | 67.3821 | 74.4847 | 24.6218 | 2,371 | .00182 | −2.5055 | 1051 | .00381 |
| 4900 | 13.502 | 57.4002 | 68.7313 | 74.7629 | 24.1361 | 2,323 | .00170 | −2.7238 | 1030 | .00370 |
| 5000 | 13.521 | 58.7414 | 70.0825 | 75.0359 | 23.6698 | 2,276 | .00183 | −2.9335 | 1010 | .00356 |
| 5100 | 13.540 | 60.1044 | 71.4355 | 75.3088 | 23.2217 | 2,232 | 0.00177 | −3.1351 | 991 | 0.00342 |
| 5200 | 13.559 | 61.4594 | 72.7905 | 75.5669 | 22.7907 | 2,189 | .00168 | −3.3291 | 973 | .00322 |
| 5300 | 13.577 | 62.8162 | 74.1473 | 75.8254 | 22.3760 | 2,148 | .00172 | −3.5159 | 955 | .00315 |
| 5400 | 13.596 | 64.1748 | 75.5059 | 76.0794 | 21.9765 | 2,108 | .00163 | −3.6959 | 938 | .00305 |
| 5500 | 13.614 | 65.5353 | 76.8664 | 76.3290 | 21.5916 | 2,070 | .00166 | −3.8695 | 921 | .00304 |
| 5600 | 13.633 | 66.8977 | 78.2288 | 76.5745 | 21.2203 | 2,033 | 0.00163 | −4.0370 | 905 | 0.00293 |
| 5700 | 13.651 | 68.2619 | 79.5930 | 76.8159 | 20.8620 | 1,998 | .00162 | −4.1987 | 890 | .00285 |
| 5800 | 13.669 | 69.6279 | 80.9590 | 77.0535 | 20.5159 | 1,963 | .00159 | −4.3550 | 875 | .00279 |
| 5900 | 13.687 | 70.9957 | 82.3268 | 77.2873 | 20.1816 | 1,930 | .00163 | −4.5061 | 860 | .00277 |
| 6000 | 13.705 | 72.3653 | 83.6964 | 77.5175 | 19.8583 | -------- | ---------- | −4.6522 | -------- | ---------- |

## TABLE XXXIV—THERMODYNAMIC PROPERTIES OF $e^-$ (ELECTRON GAS)

[Atomic weight, 5.4847x10⁻⁴]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ-H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ |
|---|---|---|---|---|
| 0 | ---------- | 0 | 60.0000 | ---------- |
| 298.16 | 4.9680 | 1.4812 | 61.4812 | 4.9882 |
| 300 | 4.9680 | 1.4904 | 61.4904 | 5.0188 |
| 400 | 4.9680 | 1.9872 | 61.9872 | 6.4480 |
| 500 | 4.9680 | 2.4840 | 62.4840 | 7.5565 |
| 600 | 4.9680 | 2.9808 | 62.9808 | 8.4623 |
| 700 | 4.9680 | 3.4776 | 63.4776 | 9.2281 |
| 800 | 4.9680 | 3.9744 | 63.9744 | 9.8915 |
| 900 | 4.9680 | 4.4712 | 64.4712 | 10.4766 |
| 1000 | 4.9680 | 4.9680 | 64.9680 | 11.0001 |
| 1100 | 4.9680 | 5.4648 | 65.4648 | 11.4736 |
| 1200 | 4.9680 | 5.9616 | 65.9616 | 11.9058 |
| 1300 | 4.9680 | 6.4584 | 66.4584 | 12.3035 |
| 1400 | 4.9680 | 6.9552 | 66.9552 | 12.6717 |
| 1500 | 4.9680 | 7.4520 | 67.4520 | 13.0144 |
| 1600 | 4.9680 | 7.9488 | 67.9488 | 13.3350 |
| 1700 | 4.9680 | 8.4456 | 68.4456 | 13.6362 |
| 1800 | 4.9680 | 8.9424 | 68.9424 | 13.9202 |
| 1900 | 4.9680 | 9.4392 | 69.4392 | 14.1888 |
| 2000 | 4.9680 | 9.9360 | 69.9360 | 14.4436 |
| 2100 | 4.9680 | 10.4328 | 70.4328 | 14.6860 |
| 2200 | 4.9680 | 10.9296 | 70.9296 | 14.9171 |
| 2300 | 4.9680 | 11.4264 | 71.4264 | 15.1379 |
| 2400 | 4.9680 | 11.9232 | 71.9232 | 15.3494 |
| 2500 | 4.9680 | 12.4200 | 72.4200 | 15.5522 |
| 2600 | 4.9680 | 12.9168 | 72.9168 | 15.7470 |
| 2700 | 4.9680 | 13.4136 | 73.4136 | 15.9345 |
| 2800 | 4.9680 | 13.9104 | 73.9104 | 16.1152 |
| 2900 | 4.9680 | 14.4072 | 74.4072 | 16.2895 |
| 3000 | 4.9680 | 14.9040 | 74.9040 | 16.4579 |
| 3100 | 4.9680 | 15.4008 | 75.4008 | 16.6208 |
| 3200 | 4.9680 | 15.8976 | 75.8976 | 16.7786 |
| 3300 | 4.9680 | 16.3944 | 76.3944 | 16.9314 |
| 3400 | 4.9680 | 16.8912 | 76.8912 | 17.0797 |
| 3500 | 4.9680 | 17.3880 | 77.3880 | 17.2237 |
| 3600 | 4.9680 | 17.8848 | 77.8848 | 17.3637 |
| 3700 | 4.9680 | 18.3816 | 78.3816 | 17.4998 |
| 3800 | 4.9680 | 18.8784 | 78.8784 | 17.6323 |
| 3900 | 4.9680 | 19.3752 | 79.3752 | 17.7614 |
| 4000 | 4.9680 | 19.8720 | 79.8720 | 17.8871 |
| 4100 | 4.9680 | 20.3688 | 80.3688 | 18.0098 |
| 4200 | 4.9680 | 20.8656 | 80.8656 | 18.1295 |
| 4300 | 4.9680 | 21.3624 | 81.3624 | 18.2464 |
| 4400 | 4.9680 | 21.8592 | 81.8592 | 18.3606 |
| 4500 | 4.9680 | 22.3560 | 82.3560 | 18.4723 |
| 4600 | 4.9680 | 22.8528 | 82.8528 | 18.5815 |
| 4700 | 4.9680 | 23.3496 | 83.3496 | 18.6883 |
| 4800 | 4.9680 | 23.8464 | 83.8464 | 18.7929 |
| 4900 | 4.9680 | 24.3432 | 84.3432 | 18.8953 |
| 5000 | 4.9680 | 24.8400 | 84.8400 | 18.9957 |
| 5100 | 4.9680 | 25.3368 | 85.3368 | 19.0941 |
| 5200 | 4.9680 | 25.8336 | 85.8336 | 19.1906 |
| 5300 | 4.9680 | 26.3304 | 86.3304 | 19.2852 |
| 5400 | 4.9680 | 26.8272 | 86.8272 | 19.3781 |
| 5500 | 4.9680 | 27.3240 | 87.3240 | 19.4692 |
| 5600 | 4.9680 | 27.8208 | 87.8208 | 19.5587 |
| 5700 | 4.9680 | 28.3176 | 88.3176 | 19.6467 |
| 5800 | 4.9680 | 28.8144 | 88.8144 | 19.7331 |
| 5900 | 4.9680 | 29.3112 | 89.3112 | 19.8180 |
| 6000 | 4.9680 | 29.8080 | 89.8080 | 19.9015 |

## TABLE XXXV—THERMODYNAMIC PROPERTIES OF $F^-$ (GAS)

[Atomic weight, 19.00]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | ---------- | 0 | 11.9781 | ---------- | ---------- | -------- | ---------- | ---------- | -------- | ---------- |
| 298.16 | 4.9680 | 1.4512 | 13.4593 | 34.7682 | 165.1619 | -------- | ---------- | 69.9505 | -------- | ---------- |
| 300 | 4.9680 | 1.4904 | 13.4685 | 34.7988 | 164.1656 | -------- | ---------- | 69.5105 | -------- | ---------- |
| 400 | 4.9680 | 1.9872 | 13.9653 | 36.2280 | 123.8037 | -------- | ---------- | 51.6419 | -------- | ---------- |
| 500 | 4.9680 | 2.4840 | 14.4621 | 37.3366 | 99.5784 | -------- | ---------- | 40.8614 | -------- | ---------- |
| 600 | 4.9680 | 2.9808 | 14.9589 | 38.2423 | 83.4222 | -------- | ---------- | 33.6357 | -------- | ---------- |
| 700 | 4.9680 | 3.4776 | 15.4557 | 39.0081 | 71.8780 | -------- | ---------- | 28.4472 | -------- | ---------- |
| 800 | 4.9680 | 3.9744 | 15.9525 | 39.6715 | 63.2172 | -------- | ---------- | 24.5355 | -------- | ---------- |
| 900 | 4.9680 | 4.4712 | 16.4493 | 40.2566 | 56.4793 | -------- | ---------- | 21.4775 | -------- | ---------- |
| 1000 | 4.9680 | 4.9679 | 16.9460 | 40.7801 | 51.0877 | 4849 | 0.00402 | 19.0187 | 2164 | 0.05463 |
| 1100 | 4.9680 | 5.4647 | 17.4428 | 41.2536 | 46.6755 | 4409 | 0.00333 | 16.9968 | 1972 | 0.04997 |
| 1200 | 4.9680 | 5.9615 | 17.9396 | 41.6858 | 42.9980 | 4042 | .00297 | 15.8035 | 1812 | .04605 |
| 1300 | 4.9680 | 6.4583 | 18.4364 | 42.0835 | 39.8858 | 3732 | .00219 | 13.8636 | 1677 | .04234 |
| 1400 | 4.9680 | 6.9551 | 18.9332 | 42.4517 | 37.2179 | 3466 | .00193 | 12.6234 | 1561 | .03953 |
| 1500 | 4.9680 | 7.4519 | 19.4300 | 42.7944 | 34.9053 | 3235 | .00172 | 11.5432 | 1461 | .03648 |
| 1600 | 4.9680 | 7.9487 | 19.9268 | 43.1150 | 32.8817 | 3034 | 0.00110 | 10.5936 | 1373 | 0.03435 |
| 1700 | 4.9680 | 8.4455 | 20.4236 | 43.4162 | 31.0959 | 2855 | .00129 | 9.7516 | 1296 | .03210 |
| 1800 | 4.9680 | 8.9423 | 20.9204 | 43.7002 | 29.5085 | 2697 | .00103 | 8.9995 | 1227 | .03021 |
| 1900 | 4.9680 | 9.4391 | 21.4172 | 43.9688 | 28.0880 | 2555 | .00110 | 8.3235 | 1165 | .02890 |
| 2000 | 4.9680 | 9.9359 | 21.9140 | 44.2236 | 26.8094 | 2428 | .00061 | 7.7121 | 1110 | .02713 |
| 2100 | 4.9680 | 10.4327 | 22.4108 | 44.4660 | 25.6526 | 2312 | 0.00079 | 7.1564 | 1059 | 0.02614 |
| 2200 | 4.9680 | 10.9295 | 22.9076 | 44.6971 | 24.6009 | 2207 | .00073 | 6.6489 | 1014 | .02473 |
| 2300 | 4.9680 | 11.4263 | 23.4044 | 44.9179 | 23.6406 | 2112 | .00040 | 6.1833 | 972 | .02380 |
| 2400 | 4.9680 | 11.9231 | 23.9012 | 45.1294 | 22.7602 | 2024 | .00030 | 5.7545 | 934 | .02270 |
| 2500 | 4.9680 | 12.4199 | 24.3980 | 45.3322 | 21.9503 | 1943 | .00039 | 5.3582 | 899 | .02173 |
| 2600 | 4.9680 | 12.9167 | 24.8948 | 45.5270 | 21.2026 | 1868 | 0.00045 | 4.9907 | 866 | 0.02106 |
| 2700 | 4.9680 | 13.4135 | 25.3916 | 45.7145 | 20.5103 | 1799 | .00040 | 4.6489 | 836 | .02023 |
| 2800 | 4.9680 | 13.9103 | 25.8884 | 45.8952 | 19.8674 | 1735 | .00032 | 4.3301 | 808 | .01958 |
| 2900 | 4.9680 | 14.4071 | 26.3852 | 46.0695 | 19.2688 | 1675 | .00037 | 4.0319 | 782 | .01893 |
| 3000 | 4.9680 | 14.9039 | 26.8820 | 46.2379 | 18.7101 | 1619 | .00044 | 3.7523 | 758 | .01818 |
| 3100 | 4.9680 | 15.4007 | 27.3788 | 46.4008 | 18.1874 | 1567 | 0.00031 | 3.4896 | 735 | 0.01761 |
| 3200 | 4.9680 | 15.8975 | 27.8756 | 46.5586 | 17.6974 | 1518 | .00030 | 3.2423 | 714 | .01704 |
| 3300 | 4.9680 | 16.3943 | 28.3724 | 46.7114 | 17.2371 | 1472 | .00036 | 3.0089 | 694 | .01658 |
| 3400 | 4.9680 | 16.8911 | 28.8692 | 46.8598 | 16.8038 | 1429 | .00021 | 2.7882 | 675 | .01614 |
| 3500 | 4.9680 | 17.3879 | 29.3660 | 47.0038 | 16.3953 | 1388 | .00024 | 2.5792 | 658 | .01542 |
| 3600 | 4.9680 | 17.8847 | 29.8628 | 47.1437 | 16.0095 | 1350 | 0.00014 | 2.3810 | 641 | 0.01506 |
| 3700 | 4.9680 | 18.3815 | 30.3596 | 47.2798 | 15.6445 | 1313 | .00027 | 2.1927 | 625 | .01473 |
| 3800 | 4.9680 | 18.8783 | 30.8564 | 47.4123 | 15.2987 | 1279 | .00005 | 2.0135 | 610 | .01429 |
| 3900 | 4.9680 | 19.3751 | 31.3532 | 47.5414 | 14.9707 | 1246 | .00010 | 1.8428 | 595 | .01415 |
| 4000 | 4.9680 | 19.8719 | 31.8500 | 47.6672 | 14.6591 | 1215 | .00016 | 1.6799 | 582 | .01365 |
| 4100 | 4.9680 | 20.3687 | 32.3468 | 47.7898 | 14.3626 | 1185 | 0.00026 | 1.5243 | 569 | 0.01332 |
| 4200 | 4.9680 | 20.8655 | 32.8436 | 47.9095 | 14.0802 | 1157 | .00013 | 1.3755 | 557 | .01297 |
| 4300 | 4.9680 | 21.3623 | 33.3404 | 48.0264 | 13.8110 | 1130 | .00018 | 1.2330 | 545 | .01274 |
| 4400 | 4.9680 | 21.8591 | 33.8372 | 48.1406 | 13.5540 | 1104 | .00017 | 1.0964 | 534 | .01243 |
| 4500 | 4.9680 | 22.3559 | 34.3340 | 48.2523 | 13.3085 | 1080 | .00012 | .9653 | 524 | .01199 |
| 4600 | 4.9680 | 22.8527 | 34.8308 | 48.3615 | 13.0736 | 1057 | 0.00001 | 0.8394 | 514 | 0.01174 |
| 4700 | 4.9680 | 23.3495 | 35.3276 | 48.4683 | 12.8487 | 1034 | .00008 | .7183 | 504 | .01150 |
| 4800 | 4.9680 | 23.8463 | 35.8244 | 48.5729 | 12.6332 | 1013 | .00007 | .6018 | 494 | .01138 |
| 4900 | 4.9680 | 24.3431 | 36.3212 | 48.6754 | 12.4264 | 992 | .00000 | .4896 | 485 | .01110 |
| 5000 | 4.9680 | 24.8399 | 36.8180 | 48.7757 | 12.2280 | 972 | .00011 | .3815 | 477 | .01087 |
| 5100 | 4.9680 | 25.3367 | 37.3148 | 48.8741 | 12.0373 | 953 | 0.00013 | 0.2771 | 468 | 0.01070 |
| 5200 | 4.9680 | 25.8335 | 37.8116 | 48.9706 | 11.8539 | 934 | .00017 | .1764 | 460 | .01051 |
| 5300 | 4.9680 | 26.3303 | 38.3084 | 49.0652 | 11.6775 | 917 | .00009 | .0791 | 453 | .01031 |
| 5400 | 4.9680 | 26.8271 | 38.8052 | 49.1581 | 11.5076 | 900 | .00016 | —.0151 | 445 | .01009 |
| 5500 | 4.9680 | 27.3239 | 39.3020 | 49.2492 | 11.3438 | 883 | .00012 | —.1061 | 439 | .00981 |
| 5600 | 4.9680 | 27.8207 | 39.7988 | 49.3387 | 11.1860 | 868 | 0.00012 | —0.1943 | 432 | 0.00961 |
| 5700 | 4.9680 | 28.3175 | 40.2956 | 49.4267 | 11.0336 | 853 | .00003 | —.2797 | 425 | .00942 |
| 5800 | 4.9680 | 28.8143 | 40.7924 | 49.5131 | 10.8865 | 838 | .00007 | —.3624 | 419 | .00928 |
| 5900 | 4.9680 | 29.3111 | 41.2892 | 49.5980 | 10.7444 | 824 | .00007 | —.4427 | 413 | .00917 |
| 6000 | 4.9680 | 29.8079 | 41.7860 | 49.6815 | 10.6070 | -------- | ---------- | —.5207 | -------- | ---------- |

## TABLE XXXVI—THERMODYNAMIC PROPERTIES OF $Li^+$ (GAS)

[Atomic weight, 6.940]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | -------- | 0 | 230.7290 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.16 | 4.9680 | 1.4812 | 232.2102 | 31.7662 | −211.5052 | -------- | -------- | −91.0660 | -------- | -------- |
| 300 | 4.9680 | 1.4903 | 232.2193 | 31.7967 | −210.2229 | -------- | -------- | −90.5026 | -------- | -------- |
| 400 | 4.9680 | 1.9871 | 232.7161 | 33.2259 | −158.2922 | -------- | -------- | −67.6371 | -------- | -------- |
| 500 | 4.9680 | 2.4839 | 233.2129 | 34.3345 | −127.1337 | -------- | -------- | −53.8629 | -------- | -------- |
| 600 | 4.9680 | 2.9807 | 233.7097 | 35.2403 | −106.3614 | -------- | -------- | −44.6436 | -------- | -------- |
| 700 | 4.9680 | 3.4775 | 234.2065 | 36.0061 | −91.5241 | -------- | -------- | −38.0325 | -------- | -------- |
| 800 | 4.9680 | 3.9743 | 234.7033 | 36.6695 | −80.3961 | -------- | -------- | −33.0546 | -------- | -------- |
| 900 | 4.9680 | 4.4711 | 235.2001 | 37.2546 | −71.7410 | -------- | -------- | −29.1679 | -------- | -------- |
| 1000 | 4.9680 | 4.9679 | 235.6969 | 37.7780 | −64.8169 | −6232 | 0.00035 | −26.0464 | −2761 | −0.05380 |
| 1100 | 4.9680 | 5.4647 | 236.1937 | 38.2515 | −59.1518 | −5665 | −0.00017 | −23.4826 | −2515 | −0.04897 |
| 1200 | 4.9680 | 5.9615 | 236.6905 | 38.6838 | −54.4308 | −5193 | −.00008 | −21.3378 | −2310 | −.04488 |
| 1300 | 4.9680 | 6.4583 | 237.1873 | 39.0814 | −50.4361 | −4793 | −.00043 | −19.5160 | −2136 | −.04179 |
| 1400 | 4.9680 | 6.9551 | 237.6841 | 39.4496 | −47.0121 | −4451 | −.00017 | −17.9485 | −1987 | −.03803 |
| 1500 | 4.9680 | 7.4519 | 238.1809 | 39.7924 | −44.0446 | −4154 | −.00035 | −16.5849 | −1858 | −.03655 |
| 1600 | 4.9680 | 7.9487 | 238.6777 | 40.1130 | −41.4480 | −3894 | −0.00051 | −15.3871 | −1745 | −0.03433 |
| 1700 | 4.9680 | 8.4455 | 239.1745 | 40.4142 | −39.1569 | −3664 | −.00104 | −14.3263 | −1646 | −.03206 |
| 1800 | 4.9680 | 8.9423 | 239.6713 | 40.6981 | −37.1203 | −3460 | −.00125 | −13.3798 | −1558 | −.03000 |
| 1900 | 4.9680 | 9.4391 | 240.1681 | 40.9668 | −35.2980 | −3277 | −.00180 | −12.5298 | −1479 | −.02840 |
| 2000 | 4.9680 | 9.9359 | 240.6649 | 41.2216 | −33.6577 | −3112 | −.00220 | −11.7619 | −1408 | −.02682 |
| 2100 | 4.9680 | 10.4327 | 241.1617 | 41.4640 | −32.1736 | −2963 | −0.00258 | −11.0646 | −1343 | −0.02585 |
| 2200 | 4.9680 | 10.9295 | 241.6585 | 41.6951 | −30.8242 | −2827 | −.00327 | −10.4283 | −1285 | −.02440 |
| 2300 | 4.9680 | 11.4263 | 242.1553 | 41.9159 | −29.5918 | −2702 | −.00407 | −9.8452 | −1231 | −.02348 |
| 2400 | 4.9680 | 11.9231 | 242.6521 | 42.1273 | −28.4619 | −2588 | −.00480 | −9.3068 | −1183 | −.02220 |
| 2500 | 4.9680 | 12.4199 | 243.1489 | 42.3301 | −27.4219 | −2482 | −.00569 | −8.8134 | −1138 | −.02111 |
| 2600 | 4.9680 | 12.9167 | 243.6457 | 42.5250 | −26.4616 | −2384 | −0.00674 | −8.3546 | −1097 | −0.02010 |
| 2700 | 4.9680 | 13.4135 | 244.1425 | 42.7125 | −25.5719 | −2293 | −.00777 | −7.9282 | −1058 | −.01944 |
| 2800 | 4.9680 | 13.9103 | 244.6393 | 42.8932 | −24.7452 | −2208 | −.00892 | −7.5309 | −1023 | −.01844 |
| 2900 | 4.9680 | 14.4071 | 245.1361 | 43.0675 | −23.9749 | −2129 | −.00983 | −7.1597 | −990 | −.01770 |
| 3000 | 4.9680 | 14.9039 | 245.6329 | 43.2359 | −23.2554 | −2055 | −.01090 | −6.8120 | −959 | −.01695 |
| 3100 | 4.9680 | 15.4007 | 246.1297 | 43.3988 | −22.5816 | −1986 | −0.01178 | −6.4857 | −930 | −0.01638 |
| 3200 | 4.9680 | 15.8975 | 246.6265 | 43.5565 | −21.9492 | −1921 | −.01268 | −6.1787 | −903 | −.01566 |
| 3300 | 4.9680 | 16.3943 | 247.1233 | 43.7094 | −21.3544 | −1860 | −.01354 | −5.8894 | −878 | −.01506 |
| 3400 | 4.9680 | 16.8911 | 247.6201 | 43.8577 | −20.7938 | −1802 | −.01444 | −5.6161 | −854 | −.01440 |
| 3500 | 4.9680 | 17.3879 | 248.1169 | 44.0017 | −20.2645 | −1748 | −.01524 | −5.3577 | −831 | −.01397 |
| 3600 | 4.9680 | 17.8847 | 248.6137 | 44.1417 | −19.7637 | −1698 | −0.01568 | −5.1129 | −810 | −0.01348 |
| 3700 | 4.9680 | 18.3815 | 249.1105 | 44.2778 | −19.2891 | −1649 | −.01645 | −4.8805 | −790 | −.01291 |
| 3800 | 4.9680 | 18.8783 | 249.6073 | 44.4103 | −18.8387 | −1603 | −.01707 | −4.6597 | −771 | −.01231 |
| 3900 | 4.9680 | 19.3751 | 250.1041 | 44.5393 | −18.4106 | −1561 | −.01745 | −4.4497 | −753 | −.01195 |
| 4000 | 4.9680 | 19.8719 | 250.6009 | 44.6651 | −18.0029 | −1520 | −.01787 | −4.2495 | −736 | −.01149 |
| 4100 | 4.9680 | 20.3687 | 251.0977 | 44.7878 | −17.6148 | −1481 | −0.01838 | −4.0585 | −720 | −0.01097 |
| 4200 | 4.9680 | 20.8655 | 251.5945 | 44.9075 | −17.2433 | −1444 | −.01869 | −3.8761 | −705 | −.01045 |
| 4300 | 4.9680 | 21.3623 | 252.0913 | 45.0244 | −16.8888 | −1410 | −.01895 | −3.7017 | −690 | −.01008 |
| 4400 | 4.9680 | 21.8591 | 252.5881 | 45.1386 | −16.5494 | −1376 | −.01922 | −3.5348 | −676 | −.00968 |
| 4500 | 4.9680 | 22.3559 | 253.0849 | 45.2502 | −16.2244 | −1345 | −.01941 | −3.3749 | −663 | −.00927 |
| 4600 | 4.9680 | 22.8527 | 253.5817 | 45.3594 | −15.9126 | −1315 | −0.01961 | −3.2215 | −650 | −0.00890 |
| 4700 | 4.9680 | 23.3495 | 254.0785 | 45.4663 | −15.6132 | −1286 | −.01978 | −3.0743 | −639 | −.00838 |
| 4800 | 4.9680 | 23.8463 | 254.5753 | 45.5709 | −15.3255 | −1259 | −.01986 | −2.9328 | −626 | −.00814 |
| 4900 | 4.9680 | 24.3431 | 255.0721 | 45.6733 | −15.0487 | −1233 | −.01990 | −2.7969 | −616 | −.00770 |
| 5000 | 4.9680 | 24.8399 | 255.5689 | 45.7737 | −14.7822 | −1208 | −.01994 | −2.0660 | −605 | −.00737 |
| 5100 | 4.9680 | 25.3367 | 256.0657 | 45.8721 | −14.5254 | −1185 | −0.01982 | −2.5400 | −595 | −0.00708 |
| 5200 | 4.9680 | 25.8335 | 256.5625 | 45.9685 | −14.2777 | −1163 | −.01967 | −2.4185 | −585 | −.00672 |
| 5300 | 4.9680 | 26.3303 | 257.0593 | 46.0632 | −14.0386 | −1142 | −.01942 | −2.3014 | −576 | −.00633 |
| 5400 | 4.9680 | 26.8271 | 257.5561 | 46.1560 | −13.8077 | −1122 | −.01930 | −2.1884 | −568 | −.00593 |
| 5500 | 4.9680 | 27.3239 | 258.0529 | 46.2472 | −13.5844 | −1103 | −.01904 | −2.0792 | −558 | −.00576 |
| 5600 | 4.9680 | 27.8207 | 258.5497 | 46.3367 | −13.3684 | −1084 | −0.01882 | −1.9738 | −550 | −0.00551 |
| 5700 | 4.9680 | 28.3175 | 259.0465 | 46.4246 | −13.1594 | −1067 | −.01853 | −1.8718 | −541 | −.00532 |
| 5800 | 4.9680 | 28.8143 | 259.5433 | 46.5110 | −12.9569 | −1050 | −.01833 | −1.7732 | −534 | −.00499 |
| 5900 | 4.9680 | 29.3111 | 260.0401 | 46.5960 | −12.7606 | −1033 | −.01813 | −1.6777 | −526 | −.00473 |
| 6000 | 4.9680 | 29.8079 | 260.5369 | 46.6795 | −12.5703 | -------- | -------- | −1.5853 | -------- | -------- |

TABLE XXXVII—THERMODYNAMIC PROPERTIES OF Li (GAS)

[Atomic weight, 6.940]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ |
|---|---|---|---|---|
| 0 | ---------- | 0 | 166.8941 | ---------- |
| 298.16 | 4.9680 | 1.4809 | 168.3750 | 33.1418 |
| 300 | 4.9680 | 1.4904 | 168.3845 | 33.1734 |
| 300 | 4.9680 | 1.9872 | 168.8818 | 34.6026 |
| 500 | 4.9680 | 2.4840 | 169.3781 | 35.7112 |
| 600 | 4.9680 | 2.9808 | 169.8749 | 36.6169 |
| 700 | 4.9680 | 3.4776 | 170.3717 | 37.3828 |
| 800 | 4.9680 | 3.9743 | 170.8684 | 38.0461 |
| 900 | 4.9680 | 4.4711 | 171.3652 | 38.6312 |
| 1000 | 4.9680 | 4.9679 | 171.8620 | 39.1547 |
| 1100 | 4.9680 | 5.4647 | 172.3588 | 39.6282 |
| 1200 | 4.9680 | 5.9615 | 172.8556 | 40.0605 |
| 1300 | 4.9681 | 6.4583 | 173.3524 | 40.4581 |
| 1400 | 4.9683 | 6.9551 | 173.8492 | 40.8263 |
| 1500 | 4.9687 | 7.4520 | 174.3461 | 41.1691 |
| 1600 | 4.9696 | 7.9489 | 174.8430 | 41.4898 |
| 1700 | 4.9711 | 8.4459 | 175.3400 | 41.7911 |
| 1800 | 4.9736 | 8.9432 | 175.8373 | 42.0753 |
| 1900 | 4.9775 | 9.4407 | 176.3348 | 42.3443 |
| 2000 | 4.9828 | 9.9388 | 176.8329 | 42.5998 |
| 2100 | 4.9908 | 10.4374 | 177.3315 | 42.8431 |
| 2200 | 5.0011 | 10.9370 | 177.8311 | 43.0755 |
| 2300 | 5.0142 | 11.4378 | 178.3319 | 43.2981 |
| 2400 | 5.0304 | 11.9400 | 178.8341 | 43.5119 |
| 2500 | 5.0506 | 12.4441 | 179.3382 | 43.7176 |
| 2600 | 5.0742 | 12.9503 | 179.8444 | 43.9162 |
| 2700 | 5.1017 | 13.4591 | 180.3532 | 44.1082 |
| 2800 | 5.1332 | 13.9709 | 180.8650 | 44.2943 |
| 2900 | 5.1687 | 14.4859 | 181.3800 | 44.4750 |
| 3000 | 5.2083 | 15.0048 | 181.8989 | 44.6509 |
| 3100 | 5.2520 | 15.5278 | 182.4219 | 44.8224 |
| 3200 | 5.2997 | 16.0554 | 182.9495 | 44.9899 |
| 3300 | 5.3497 | 16.5879 | 183.4820 | 45.1538 |
| 3400 | 5.4034 | 17.1255 | 184.0196 | 45.3143 |
| 3500 | 5.4619 | 17.6658 | 184.5629 | 45.4718 |
| 3600 | 5.5223 | 18.2180 | 185.1121 | 45.6265 |
| 3700 | 5.5841 | 18.7733 | 185.6674 | 45.7786 |
| 3800 | 5.6495 | 19.3350 | 186.2291 | 45.9284 |
| 3900 | 5.7182 | 19.9034 | 186.7975 | 46.0760 |
| 4000 | 5.7870 | 20.4786 | 187.3727 | 46.2217 |
| 4100 | 5.8586 | 21.0609 | 187.9550 | 46.3655 |
| 4200 | 5.9316 | 21.6504 | 188.5445 | 46.5075 |
| 4300 | 6.0053 | 22.2473 | 189.1414 | 46.6480 |
| 4400 | 6.0813 | 22.8516 | 189.7457 | 46.7869 |
| 4500 | 6.1576 | 23.4636 | 190.3577 | 46.9244 |
| 4600 | 6.2356 | 24.0832 | 190.9773 | 47.0606 |
| 4700 | 6.3129 | 24.7106 | 191.6047 | 47.1955 |
| 4800 | 6.3919 | 25.3459 | 192.2400 | 47.3293 |
| 4900 | 6.4702 | 25.9890 | 192.8831 | 47.4619 |
| 5000 | 6.5495 | 26.6400 | 193.5341 | 47.5934 |
| 5100 | 6.6275 | 27.2988 | 194.1929 | 47.7238 |
| 5200 | 6.7059 | 27.9655 | 194.8596 | 47.8533 |
| 5300 | 6.7833 | 28.6399 | 195.5340 | 47.9818 |
| 5400 | 6.8608 | 29.3222 | 196.2163 | 48.1093 |
| 5500 | 6.9373 | 30.0121 | 196.9062 | 48.2359 |
| 5600 | 7.0130 | 30.7096 | 197.6037 | 48.3616 |
| 5700 | 7.0880 | 31.4146 | 198.3087 | 48.4863 |
| 5800 | 7.1617 | 32.1271 | 199.0212 | 48.6102 |
| 5900 | 7.2348 | 32.8469 | 199.7410 | 48.7333 |
| 6000 | 7.3068 | 33.5740 | 200.4681 | 48.8555 |

## TABLE XXXVIII—THERMODYNAMIC PROPERTIES OF LiF (GAS)

[Molecular weight, 25.940]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $\frac{\Delta H^\circ}{RT}$ | $\delta\left(\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ $a$ | $b$ | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ $c$ | $d$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -------- | 0 | 77.9204 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.16 | 7.0836 | 2.0796 | 80.0000 | 47.1209 | 233.2688 | -------- | -------- | 96.9757 | -------- | -------- |
| 300 | 7.0872 | 2.0926 | 80.0130 | 47.1645 | 231.8488 | -------- | -------- | 95.4543 | -------- | -------- |
| 400 | 7.3314 | 2.8129 | 80.7333 | 49.2349 | 174.2849 | -------- | -------- | 70.2551 | -------- | -------- |
| 500 | 7.6048 | 3.5598 | 81.4802 | 50.9005 | 139.7116 | -------- | -------- | 55.1023 | -------- | -------- |
| 600 | 7.8484 | 4.3328 | 82.2532 | 52.3092 | 116.6850 | -------- | -------- | 44.9810 | -------- | -------- |
| 700 | 8.0471 | 5.1280 | 83.0484 | 53.5345 | 100.1316 | -------- | -------- | 37.7391 | -------- | -------- |
| 800 | 8.2042 | 5.9409 | 83.8613 | 54.6197 | 87.7402 | -------- | -------- | 32.2995 | -------- | -------- |
| 900 | 8.3275 | 6.7677 | 84.6881 | 55.5935 | 78.0930 | -------- | -------- | 28.0630 | -------- | -------- |
| 1000 | 8.4245 | 7.6055 | 85.5259 | 56.4761 | 70.3683 | 6931 | 0.02399 | 24.6694 | 3039 | 0.01707 |
| 1100 | 8.5016 | 8.4518 | 86.3722 | 57.2826 | 64.0434 | 6306 | 0.01920 | 21.8896 | 2765 | 0.01483 |
| 1200 | 8.5635 | 9.3050 | 87.2254 | 58.0250 | 58.7692 | 5785 | .01560 | 19.5706 | 2536 | .01353 |
| 1300 | 8.6137 | 10.1639 | 88.0843 | 58.7124 | 54.3036 | 5344 | .01236 | 17.6063 | 2343 | .01173 |
| 1400 | 8.6549 | 11.0273 | 88.9477 | 59.3523 | 50.4741 | 4965 | .01050 | 15.9210 | 2177 | .01077 |
| 1500 | 8.6890 | 11.8945 | 89.8149 | 59.9506 | 47.1536 | 4637 | .00858 | 14.4589 | 2033 | .00988 |
| 1600 | 8.7175 | 12.7649 | 90.6853 | 60.5123 | 44.2469 | 4350 | 0.00668 | 13.1784 | 1907 | 0.00904 |
| 1700 | 8.7416 | 13.6378 | 91.5582 | 61.0415 | 41.6814 | 4096 | .00564 | 12.0476 | 1796 | .00842 |
| 1800 | 8.7621 | 14.5130 | 92.4334 | 61.5417 | 39.4002 | 3871 | .00433 | 11.0414 | 1697 | .00774 |
| 1900 | 8.7796 | 15.3901 | 93.3105 | 62.0159 | 37.3585 | 3669 | .00330 | 10.1405 | 1609 | .00710 |
| 2000 | 8.7948 | 16.2688 | 94.1892 | 62.4666 | 35.5207 | 3488 | .00215 | 9.3289 | 1529 | .00080 |
| 2100 | 8.8079 | 17.1489 | 95.0693 | 62.8961 | 33.8576 | 3324 | 0.00109 | 8.5940 | 1457 | 0.00633 |
| 2200 | 8.8194 | 18.0303 | 95.9507 | 63.3061 | 32.3456 | 3176 | −.00037 | 7.9254 | 1392 | .00578 |
| 2300 | 8.8295 | 18.9128 | 96.8332 | 63.6983 | 30.9651 | 3040 | −.00117 | 7.3144 | 1332 | .00560 |
| 2400 | 8.8384 | 19.7961 | 97.7165 | 64.0743 | 29.6996 | 2917 | −.00280 | 6.7538 | 1277 | .00540 |
| 2500 | 8.8463 | 20.6804 | 98.6008 | 64.4353 | 28.5356 | 2803 | −.00378 | 6.2376 | 1226 | .00526 |
| 2600 | 8.8534 | 21.5654 | 99.4858 | 64.7824 | 27.4613 | 2698 | −0.00486 | 5.7608 | 1179 | 0.00523 |
| 2700 | 8.8597 | 22.4510 | 100.3714 | 65.1166 | 26.4669 | 2602 | −.00639 | 5.3189 | 1136 | .00499 |
| 2800 | 8.8653 | 23.3373 | 101.2577 | 65.4389 | 25.5440 | 2512 | −.00731 | 4.9082 | 1095 | .00511 |
| 2900 | 8.8704 | 24.2241 | 102.1445 | 65.7501 | 24.6851 | 2429 | −.00867 | 4.5255 | 1058 | .00483 |
| 3000 | 8.8750 | 25.1113 | 103.0317 | 66.0509 | 23.8841 | 2351 | −.00969 | 4.1680 | 1023 | .00480 |
| 3100 | 8.8792 | 25.9990 | 103.9194 | 66.3420 | 23.1354 | 2279 | −0.01079 | 3.8332 | 990 | 0.00473 |
| 3200 | 8.8830 | 26.8871 | 104.8075 | 66.6239 | 22.4340 | 2210 | −.01160 | 3.5191 | 959 | .00479 |
| 3300 | 8.8865 | 27.7756 | 105.6960 | 66.8973 | 21.7759 | 2146 | −.01248 | 3.2237 | 930 | .00477 |
| 3400 | 8.8897 | 28.6644 | 106.5848 | 67.1627 | 21.1572 | 2088 | −.01397 | 2.9454 | 903 | .00470 |
| 3500 | 8.8926 | 29.5535 | 107.4739 | 67.4204 | 20.5746 | 2030 | −.01439 | 2.6827 | 877 | .00469 |
| 3600 | 8.8953 | 30.4429 | 108.3633 | 67.6710 | 20.0251 | 1975 | −0.01473 | 2.4344 | 852 | 0.00493 |
| 3700 | 8.8978 | 31.3326 | 109.2530 | 67.9147 | 19.5061 | 1925 | −.01568 | 2.1992 | 829 | .00484 |
| 3800 | 8.9001 | 32.2225 | 110.1429 | 68.1520 | 19.0152 | 1878 | −.01674 | 1.9762 | 807 | .00498 |
| 3900 | 8.9022 | 33.1126 | 111.0330 | 68.3832 | 18.5504 | 1830 | −.01670 | 1.7643 | 786 | .00510 |
| 4000 | 8.9041 | 34.0029 | 111.9233 | 68.6087 | 18.1096 | 1787 | −.01735 | 1.5627 | 766 | .00507 |
| 4100 | 8.9060 | 34.8934 | 112.8138 | 68.8286 | 17.6911 | 1745 | −0.01788 | 1.3708 | 748 | 0.00500 |
| 4200 | 8.9076 | 35.7841 | 113.7045 | 69.0432 | 17.2935 | 1704 | −.01788 | 1.1877 | 729 | .00517 |
| 4300 | 8.9092 | 36.6749 | 114.5953 | 69.2528 | 16.9151 | 1668 | −.01879 | 1.0130 | 712 | .00528 |
| 4400 | 8.9107 | 37.5659 | 115.4863 | 69.4576 | 16.5548 | 1630 | −.01872 | .8459 | 696 | .00523 |
| 4500 | 8.9121 | 38.4571 | 116.3775 | 69.6579 | 16.2113 | 1596 | −.01926 | .6860 | 680 | .00537 |
| 4600 | 8.9134 | 39.3484 | 117.2688 | 69.8538 | 15.8836 | 1561 | −0.01923 | 0.5326 | 665 | 0.00541 |
| 4700 | 8.9146 | 40.2398 | 118.1602 | 70.0445 | 15.5707 | 1529 | −.01944 | .3859 | 651 | .00538 |
| 4800 | 8.9157 | 41.1313 | 119.0517 | 70.2332 | 15.2716 | 1497 | −.01941 | .2449 | 636 | .00560 |
| 4900 | 8.9168 | 42.0229 | 119.9433 | 70.4170 | 14.9855 | 1468 | −.01970 | .1095 | 623 | .00570 |
| 5000 | 8.9178 | 42.9146 | 120.8350 | 70.5972 | 14.7116 | 1437 | −.01936 | −.0208 | 611 | .00560 |
| 5100 | 8.9187 | 43.8064 | 121.7268 | 70.7738 | 14.4492 | 1409 | −0.01946 | −0.1462 | 598 | 0.00580 |
| 5200 | 8.9196 | 44.6984 | 122.6188 | 70.9470 | 14.1977 | 1381 | −.01917 | −.2670 | 586 | .00583 |
| 5300 | 8.9204 | 45.5904 | 123.5108 | 71.1169 | 13.9563 | 1355 | −.01933 | −.3834 | 575 | .00592 |
| 5400 | 8.9212 | 46.4824 | 124.4028 | 71.2836 | 13.7247 | 1328 | −.01885 | −.4958 | 564 | .00595 |
| 5500 | 8.9220 | 47.3746 | 125.2950 | 71.4474 | 13.5021 | 1303 | −.01878 | −.6043 | 553 | .00605 |
| 5600 | 8.9227 | 48.2668 | 126.1872 | 71.6081 | 13.2882 | 1279 | −0.01869 | −0.7091 | 543 | 0.00604 |
| 5700 | 8.9234 | 49.1591 | 127.0795 | 71.7661 | 13.0825 | 1255 | −.01828 | −.8104 | 534 | .00603 |
| 5800 | 8.9240 | 50.0515 | 127.9719 | 71.9213 | 12.8844 | 1232 | −.01811 | −.9085 | 524 | .00609 |
| 5900 | 8.9246 | 50.9439 | 128.8643 | 72.0738 | 12.6937 | 1209 | −.01780 | −1.0034 | 515 | .00617 |
| 6000 | 8.9252 | 51.8364 | 129.7568 | 72.2238 | 12.5100 | -------- | -------- | −1.0954 | -------- | -------- |

## TABLE XXXIX—THERMODYNAMIC PROPERTIES OF LiH (GAS)

[Molecular weight, 7.948]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | -------- | 0 | 190.3225 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.16 | 7.0763 | 2.0793 | 192.4018 | 40.7963 | 105.9633 | -------- | -------- | 41.7055 | -------- | -------- |
| 300 | 7.0797 | 2.0923 | 192.4148 | 40.8398 | 105.3228 | -------- | -------- | 41.4233 | -------- | -------- |
| 400 | 7.3175 | 2.8115 | 193.1340 | 42.9072 | 79.3373 | -------- | -------- | 29.9651 | -------- | -------- |
| 500 | 7.5879 | 3.5568 | 193.8798 | 44.5692 | 63.7197 | -------- | -------- | 23.0611 | -------- | -------- |
| 600 | 7.8313 | 4.3281 | 194.6506 | 45.9748 | 53.2862 | -------- | -------- | 18.4412 | -------- | -------- |
| 700 | 8.0312 | 5.1216 | 195.4441 | 47.1975 | 45.8178 | -------- | -------- | 15.1301 | -------- | -------- |
| 800 | 8.1899 | 5.9330 | 196.2555 | 48.2807 | 40.2052 | -------- | -------- | 12.6394 | -------- | -------- |
| 900 | 8.3148 | 6.7585 | 197.0810 | 49.2529 | 35.8319 | -------- | -------- | 10.6968 | -------- | -------- |
| 1000 | 8.4134 | 7.5951 | 197.9176 | 50.1842 | 32.3277 | 3136 | 0.02009 | 9.1388 | 1388 | 0.01598 |
| 1100 | 8.4918 | 8.4403 | 198.7628 | 50.9398 | 29.4567 | 2856 | 0.01550 | 7.8610 | 1264 | 0.01387 |
| 1200 | 8.5548 | 9.2927 | 199.6152 | 51.6814 | 27.0612 | 2621 | .01305 | 6.7938 | 1160 | .01269 |
| 1300 | 8.6060 | 10.1507 | 200.4732 | 52.3681 | 25.0320 | 2423 | .01019 | 5.8888 | 1072 | .01149 |
| 1400 | 8.6481 | 11.0134 | 201.3359 | 53.0074 | 23.2911 | 2252 | .00877 | 5.1116 | 997 | .01033 |
| 1500 | 8.6829 | 11.8899 | 202.2024 | 53.6053 | 21.7810 | 2104 | .00730 | 4.4366 | 932 | .00930 |
| 1600 | 8.7121 | 12.7497 | 203.0722 | 54.1666 | 20.4587 | 1975 | 0.00574 | 3.8448 | 875 | 0.00839 |
| 1700 | 8.7367 | 13.6221 | 203.9446 | 54.6955 | 19.2912 | 1861 | .00451 | 3.3217 | 824 | .00812 |
| 1800 | 8.7576 | 14.4969 | 204.8194 | 55.1955 | 18.2528 | 1759 | .00371 | 2.8558 | 780 | .00707 |
| 1900 | 8.7756 | 15.3735 | 205.6960 | 55.6694 | 17.3232 | 1669 | .00230 | 2.4382 | 739 | .00700 |
| 2000 | 8.7911 | 16.2518 | 206.5743 | 56.1200 | 16.4865 | 1588 | .00121 | 2.0617 | 703 | .00644 |
| 2100 | 8.8046 | 17.1316 | 207.4541 | 56.5492 | 15.7291 | 1514 | 0.00042 | 1.7205 | 670 | 0.00625 |
| 2200 | 8.8162 | 18.0127 | 208.3352 | 56.9591 | 15.0405 | 1448 | −.00087 | 1.4097 | 640 | .00604 |
| 2300 | 8.8266 | 18.8948 | 209.2173 | 57.3512 | 14.4118 | 1387 | −.00172 | 1.1254 | 613 | .00558 |
| 2400 | 8.8358 | 19.7779 | 210.1004 | 57.7270 | 13.8356 | 1332 | −.00290 | .8644 | 588 | .00530 |
| 2500 | 8.8439 | 20.6619 | 210.9844 | 58.0879 | 13.3057 | 1282 | −.00428 | .6239 | 565 | .00519 |
| 2600 | 8.8511 | 21.5467 | 211.8692 | 58.4349 | 12.8169 | 1235 | −0.00511 | 0.4014 | 543 | 0.00519 |
| 2700 | 8.8576 | 22.4321 | 212.7546 | 58.7691 | 12.3646 | 1193 | −.00647 | .1951 | 524 | .00486 |
| 2800 | 8.8634 | 23.3182 | 213.6407 | 59.0913 | 11.9450 | 1154 | −.00778 | .0031 | 505 | .00486 |
| 2900 | 8.8686 | 24.2048 | 214.5273 | 59.4024 | 11.5548 | 1117 | −.00883 | −.1759 | 488 | .00483 |
| 3000 | 8.8733 | 25.0918 | 215.4143 | 59.7032 | 11.1913 | 1083 | −.00975 | −.3434 | 472 | .00464 |
| 3100 | 8.8776 | 25.9794 | 216.3019 | 59.9942 | 10.8517 | 1052 | −0.01115 | −0.5001 | 457 | 0.00459 |
| 3200 | 8.8815 | 26.8673 | 217.1898 | 60.2761 | 10.5341 | 1021 | −.01159 | −.6477 | 443 | .00456 |
| 3300 | 8.8851 | 27.7557 | 218.0782 | 60.5495 | 10.2368 | 993 | −.01258 | −.7865 | 429 | .00472 |
| 3400 | 8.8884 | 28.6444 | 218.9669 | 60.8148 | 9.9568 | 969 | −.01416 | −.9174 | 417 | .00456 |
| 3500 | 8.8918 | 29.5333 | 219.8558 | 61.0724 | 9.6941 | 943 | −.01454 | −1.0411 | 404 | .00478 |
| 3600 | 8.8941 | 30.4226 | 220.7451 | 61.3230 | 9.4467 | 918 | −0.01491 | −1.1581 | 394 | 0.00461 |
| 3700 | 8.8966 | 31.3121 | 221.6346 | 61.5667 | 9.2135 | 897 | −.01595 | −1.2692 | 383 | .00461 |
| 3800 | 8.8990 | 32.2019 | 222.5244 | 61.8040 | 8.9934 | 877 | −.01687 | −1.3746 | 373 | .00466 |
| 3900 | 8.9011 | 33.0919 | 223.4144 | 62.0352 | 8.7854 | 854 | −.01670 | −1.4749 | 363 | .00475 |
| 4000 | 8.9032 | 33.9821 | 224.3046 | 62.2605 | 8.5886 | 836 | −.01760 | −1.5704 | 354 | .00476 |
| 4100 | 8.9050 | 34.8726 | 225.1951 | 62.4804 | 8.4023 | 817 | −0.01792 | −1.6615 | 345 | 0.00486 |
| 4200 | 8.9068 | 35.7631 | 226.0856 | 62.6950 | 8.2257 | 798 | −.01808 | −1.7485 | 336 | .00506 |
| 4300 | 8.9084 | 36.6539 | 226.9764 | 62.9046 | 8.0582 | 783 | −.01885 | −1.8317 | 328 | .00505 |
| 4400 | 8.9099 | 37.5448 | 227.8673 | 63.1094 | 7.8991 | 765 | −.01880 | −1.9113 | 321 | .00507 |
| 4500 | 8.9113 | 38.4395 | 228.7584 | 63.3097 | 7.7479 | 750 | −.01924 | −1.9877 | 313 | .00526 |
| 4600 | 8.9126 | 39.3271 | 229.6496 | 63.5056 | 7.6041 | 733 | −0.01906 | −2.0610 | 305 | 0.00541 |
| 4700 | 8.9138 | 40.2184 | 230.5409 | 63.6972 | 7.4672 | 720 | −.01970 | −2.1318 | 299 | .00541 |
| 4800 | 8.9150 | 41.1098 | 231.4323 | 63.8849 | 7.3369 | 704 | −.01947 | −2.1990 | 292 | .00561 |
| 4900 | 8.9161 | 42.0014 | 232.3239 | 64.0688 | 7.2127 | 691 | −.01970 | −2.2642 | 285 | .00570 |
| 5000 | 8.9171 | 42.8933 | 233.2156 | 64.2489 | 7.0942 | 675 | −.01925 | −2.3269 | 279 | .00579 |
| 5100 | 8.9181 | 43.7848 | 234.1073 | 64.4255 | 6.9811 | 663 | −0.01950 | −2.3874 | 274 | 0.00581 |
| 5200 | 8.9190 | 44.6767 | 234.9992 | 64.5987 | 6.8731 | 649 | −.01935 | −2.4459 | 267 | .00602 |
| 5300 | 8.9199 | 45.5686 | 235.8911 | 64.7686 | 6.7700 | 637 | −.01936 | −2.5023 | 262 | .00598 |
| 5400 | 8.9207 | 46.4606 | 236.7831 | 64.9353 | 6.6714 | 624 | −.01905 | −2.5568 | 257 | .00607 |
| 5500 | 8.9215 | 47.3527 | 237.6752 | 65.0990 | 6.5770 | 611 | −.01881 | −2.6096 | 251 | .00626 |
| 5600 | 8.9222 | 48.2449 | 238.5674 | 65.2598 | 6.4867 | 599 | −0.01859 | −2.6607 | 247 | 0.00627 |
| 5700 | 8.9229 | 49.1372 | 239.4597 | 65.4177 | 6.4002 | 587 | −.01841 | −2.7103 | 241 | .00645 |
| 5800 | 8.9236 | 50.0295 | 240.3520 | 65.5729 | 6.3174 | 576 | −.01823 | −2.7583 | 236 | .00660 |
| 5900 | 8.9242 | 50.9219 | 241.2444 | 65.7254 | 6.2380 | 564 | −.01780 | −2.8049 | 232 | .00663 |
| 6000 | 8.9248 | 51.8144 | 242.1369 | 65.8754 | 6.1618 | -------- | -------- | −2.8502 | -------- | -------- |

## TABLE XL—THERMODYNAMIC PROPERTIES OF N (GAS)

[Atomic weight, 14.008]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ |
|---|---|---|---|---|
| 0 | ---------- | 0 | 85.9696 | ---------- |
| 298.16 | 4.9680 | 1.4812 | 87.4508 | 36.6145 |
| 300 | 4.9680 | 1.4904 | 87.4600 | 36.6450 |
| 400 | 4.9680 | 1.9872 | 87.9568 | 38.0742 |
| 500 | 4.9680 | 2.4840 | 88.4536 | 39.1828 |
| 600 | 4.9680 | 2.9808 | 88.9504 | 40.0885 |
| 700 | 4.9680 | 3.4776 | 89.4472 | 40.8544 |
| 800 | 4.9680 | 3.9744 | 89.9440 | 41.5177 |
| 900 | 4.9680 | 4.4712 | 90.4408 | 42.1029 |
| 1000 | 4.9680 | 4.9680 | 90.9376 | 42.6263 |
| 1100 | 4.9680 | 5.4648 | 91.4344 | 43.0998 |
| 1200 | 4.9680 | 5.9616 | 91.9312 | 43.5321 |
| 1300 | 4.9680 | 6.4584 | 92.4280 | 43.9297 |
| 1400 | 4.9680 | 6.9552 | 92.9248 | 44.2979 |
| 1500 | 4.9680 | 7.4520 | 93.4216 | 44.6406 |
| 1600 | 4.9680 | 7.9488 | 93.9184 | 44.9613 |
| 1700 | 4.9681 | 8.4456 | 94.4152 | 45.2625 |
| 1800 | 4.9683 | 8.9424 | 94.9120 | 45.5464 |
| 1900 | 4.9685 | 9.4393 | 95.4089 | 45.8151 |
| 2000 | 4.9690 | 9.9362 | 95.9058 | 46.0699 |
| 2100 | 4.9697 | 10.4331 | 96.4027 | 46.3124 |
| 2200 | 4.9708 | 10.9301 | 96.8997 | 46.5436 |
| 2300 | 4.9724 | 11.4273 | 97.3969 | 46.7646 |
| 2400 | 4.9746 | 11.9246 | 97.8942 | 46.9763 |
| 2500 | 4.9777 | 12.4222 | 98.3918 | 47.1794 |
| 2600 | 4.9816 | 12.9202 | 98.8898 | 47.3747 |
| 2700 | 4.9869 | 13.4186 | 99.3882 | 47.5628 |
| 2800 | 4.9935 | 13.9177 | 99.8873 | 47.7443 |
| 2900 | 5.0015 | 14.4174 | 100.3870 | 47.9197 |
| 3000 | 5.0108 | 14.9180 | 100.8876 | 48.0894 |
| 3100 | 5.0222 | 15.4197 | 101.3893 | 48.2539 |
| 3200 | 5.0354 | 15.9226 | 101.8922 | 48.4135 |
| 3300 | 5.0504 | 16.4268 | 102.3964 | 48.5687 |
| 3400 | 5.0675 | 16.9327 | 102.9023 | 48.7197 |
| 3500 | 5.0866 | 17.4404 | 103.4100 | 48.8669 |
| 3600 | 5.1079 | 17.9502 | 103.9198 | 49.0105 |
| 3700 | 5.1312 | 18.4621 | 104.4317 | 49.1508 |
| 3800 | 5.1567 | 18.9765 | 104.9461 | 49.2880 |
| 3900 | 5.1844 | 19.4936 | 105.4632 | 49.4223 |
| 4000 | 5.2143 | 20.0135 | 105.9831 | 49.5539 |
| 4100 | 5.2461 | 20.5365 | 106.5061 | 49.6830 |
| 4200 | 5.2800 | 21.0628 | 107.0324 | 49.8099 |
| 4300 | 5.3158 | 21.5926 | 107.5622 | 49.9345 |
| 4400 | 5.3533 | 22.1261 | 108.0957 | 50.0572 |
| 4500 | 5.3927 | 22.6634 | 108.6330 | 50.1779 |
| 4600 | 5.4335 | 23.2047 | 109.1743 | 50.2969 |
| 4700 | 5.4759 | 23.7502 | 109.7198 | 50.4142 |
| 4800 | 5.5197 | 24.2999 | 110.2695 | 50.5299 |
| 4900 | 5.5646 | 24.8542 | 110.8238 | 50.6442 |
| 5000 | 5.6109 | 25.4129 | 111.3825 | 50.7571 |
| 5100 | 5.6581 | 25.9764 | 111.9460 | 50.8687 |
| 5200 | 5.7063 | 26.5446 | 112.5142 | 50.9790 |
| 5300 | 5.7553 | 27.1177 | 113.0873 | 51.0882 |
| 5400 | 5.8052 | 27.6957 | 113.6653 | 51.1962 |
| 5500 | 5.8558 | 28.2788 | 114.2484 | 51.3032 |
| 5600 | 5.9070 | 28.8669 | 114.8365 | 51.4092 |
| 5700 | 5.9588 | 29.4602 | 115.4298 | 51.5142 |
| 5800 | 6.0114 | 30.0587 | 116.0283 | 51.6183 |
| 5900 | 6.0644 | 30.6625 | 116.6321 | 51.7215 |
| 6000 | 6.1179 | 31.2716 | 117.2412 | 51.8238 |

## TABLE XLI—THERMODYNAMIC PROPERTIES OF $N_2$ (GAS)

[Molecular weight, 28.016]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ $a$ | $-b$ | $\log K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ $c$ | $d$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -------- | 0 | 1.6992 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.16 | 6.960 | 2.0723 | 3.7715 | 45.767 | 288.8283 | -------- | -------- | 119.4348 | -------- | -------- |
| 300 | 6.961 | 2.0851 | 3.7843 | 45.809 | 287.0664 | -------- | -------- | 118.6656 | -------- | -------- |
| 400 | 6.991 | 2.7824 | 4.4816 | 47.818 | 215.6725 | -------- | -------- | 87.4738 | -------- | -------- |
| 500 | 7.070 | 3.4850 | 5.1842 | 49.385 | 172.8306 | -------- | -------- | 68.7259 | -------- | -------- |
| 600 | 7.197 | 4.1980 | 5.8972 | 50.685 | 144.2610 | -------- | -------- | 56.2064 | -------- | -------- |
| 700 | 7.351 | 4.9253 | 6.6245 | 51.805 | 123.8438 | -------- | -------- | 47.2492 | -------- | -------- |
| 800 | 7.512 | 5.6686 | 7.3678 | 52.797 | 108.5207 | -------- | -------- | 40.5214 | -------- | -------- |
| 900 | 7.671 | 6.4280 | 8.1272 | 53.692 | 96.5937 | -------- | -------- | 35.2815 | -------- | -------- |
| 1000 | 7.816 | 7.2025 | 8.9017 | 54.5090 | 87.0447 | 8565 | 0.03284 | 31.0841 | 3756 | 0.02405 |
| 1100 | 7.947 | 7.9907 | 9.6899 | 55.2601 | 79.2255 | 7790 | 0.02943 | 27.6455 | 3418 | 0.02057 |
| 1200 | 8.063 | 8.7912 | 10.4904 | 55.9565 | 72.7044 | 7145 | .02594 | 24.7766 | 3186 | .01779 |
| 1300 | 8.165 | 9.6026 | 11.3018 | 56.6060 | 67.1823 | 6600 | .02241 | 22.3465 | 2898 | .01510 |
| 1400 | 8.253 | 10.4235 | 12.1227 | 57.2143 | 62.4456 | 6133 | .01923 | 20.2614 | 2693 | .01347 |
| 1500 | 8.330 | 11.2526 | 12.9518 | 57.7863 | 58.3377 | 5727 | .01732 | 18.4526 | 2515 | .01233 |
| 1600 | 8.399 | 12.0891 | 13.7883 | 58.3261 | 54.7410 | 5373 | 0.01481 | 16.8684 | 2360 | 0.01076 |
| 1700 | 8.459 | 12.9320 | 14.6312 | 58.8371 | 51.5656 | 5060 | .01309 | 15.4694 | 2223 | .00970 |
| 1800 | 8.512 | 13.7805 | 15.4797 | 59.3221 | 48.7414 | 4781 | .01188 | 14.2247 | 2101 | .00881 |
| 1900 | 8.560 | 14.6341 | 16.3333 | 59.7836 | 46.2132 | 4532 | .01050 | 13.1101 | 1991 | .00830 |
| 2000 | 8.602 | 15.4922 | 17.1914 | 60.2237 | 43.9367 | 4308 | .00927 | 12.1063 | 1893 | .00757 |
| 2100 | 8.640 | 16.3543 | 18.0535 | 60.6443 | 41.8760 | 4105 | 0.00819 | 11.1973 | 1804 | 0.00700 |
| 2200 | 8.674 | 17.2200 | 18.9192 | 61.0471 | 40.0019 | 3921 | .00702 | 10.3703 | 1728 | .00647 |
| 2300 | 8.705 | 18.0890 | 19.7882 | 61.4333 | 38.2901 | 3753 | .00595 | 9.6147 | 1649 | .00602 |
| 2400 | 8.733 | 18.9609 | 20.6601 | 61.8044 | 36.7204 | 3599 | .00490 | 8.9216 | 1581 | .00570 |
| 2500 | 8.759 | 19.8355 | 21.5347 | 62.1614 | 35.2759 | 3457 | .00419 | 8.2835 | 1519 | .00527 |
| 2600 | 8.783 | 20.7126 | 22.4118 | 62.5054 | 33.9421 | 3327 | 0.00298 | 7.6940 | 1461 | 0.00409 |
| 2700 | 8.805 | 21.5920 | 23.2912 | 62.8373 | 32.7069 | 3207 | .00174 | 7.1479 | 1407 | .00500 |
| 2800 | 8.8253 | 22.4735 | 24.1727 | 63.1579 | 31.5598 | 3096 | .00061 | 6.6404 | 1357 | .00477 |
| 2900 | 8.8440 | 23.3570 | 25.0562 | 63.4679 | 30.4916 | 2992 | −.00043 | 6.1677 | 1311 | .00460 |
| 3000 | 8.8610 | 24.2422 | 25.9414 | 63.7680 | 29.4947 | 2896 | −.00169 | 5.7261 | 1268 | .00427 |
| 3100 | 8.8774 | 25.1291 | 26.8283 | 64.0588 | 28.5622 | 2806 | −0.00268 | 5.3128 | 1227 | 0.00436 |
| 3200 | 8.8928 | 26.0177 | 27.7169 | 64.3409 | 27.6880 | 2722 | −.00395 | 4.9250 | 1189 | .00420 |
| 3300 | 8.9073 | 26.9077 | 28.6069 | 64.6148 | 26.8671 | 2644 | −.00525 | 4.5605 | 1153 | .00418 |
| 3400 | 8.9210 | 27.7991 | 29.4983 | 64.8809 | 26.0947 | 2570 | −.00628 | 4.2172 | 1120 | .00390 |
| 3500 | 8.9340 | 28.6918 | 30.3910 | 65.1397 | 25.3667 | 2501 | −.00772 | 3.8933 | 1088 | .00388 |
| 3600 | 8.9462 | 29.5858 | 31.2850 | 65.3915 | 24.6797 | 2436 | −0.00878 | 3.5872 | 1056 | 0.00385 |
| 3700 | 8.9577 | 30.4810 | 32.1802 | 65.6368 | 24.0301 | 2375 | −.01020 | 3.2974 | 1029 | .00391 |
| 3800 | 8.9686 | 31.3773 | 33.0765 | 65.8758 | 23.4153 | 2317 | −.01140 | 3.0227 | 1002 | .00398 |
| 3900 | 8.9790 | 32.2747 | 33.9739 | 66.1089 | 22.8326 | 2262 | −.01240 | 2.7618 | 976 | .00400 |
| 4000 | 8.9890 | 33.1731 | 34.8723 | 66.3364 | 22.2795 | 2210 | −.01362 | 2.5138 | 952 | .00390 |
| 4100 | 8.9987 | 34.0725 | 35.7717 | 66.5585 | 21.7541 | 2160 | −0.01459 | 2.2777 | 928 | 0.00405 |
| 4200 | 9.0082 | 34.9729 | 36.6721 | 66.7754 | 21.2544 | 2113 | −.01570 | 2.0527 | 906 | .00410 |
| 4300 | 9.0174 | 35.8741 | 37.5733 | 66.9875 | 20.7787 | 2068 | −.01660 | 1.8379 | 885 | .00406 |
| 4400 | 9.0263 | 36.7763 | 38.4755 | 67.1949 | 20.3253 | 2026 | −.01772 | 1.6327 | 864 | .00420 |
| 4500 | 9.0350 | 37.6794 | 39.3786 | 67.3979 | 19.8928 | 1984 | −.01840 | 1.4365 | 845 | .00420 |
| 4600 | 9.0435 | 38.5833 | 40.2825 | 67.5965 | 19.4799 | 1945 | −0.01923 | 1.2486 | 827 | 0.00414 |
| 4700 | 9.0518 | 39.4881 | 41.1873 | 67.7911 | 19.0853 | 1907 | −.02009 | 1.0685 | 809 | .00426 |
| 4800 | 9.0600 | 40.3937 | 42.0929 | 67.9818 | 18.7081 | 1870 | −.02053 | .8957 | 792 | .00427 |
| 4900 | 9.0681 | 41.3001 | 42.9993 | 68.1687 | 18.3470 | 1835 | −.02120 | .7298 | 775 | .00450 |
| 5000 | 9.0760 | 42.2073 | 43.9065 | 68.3520 | 18.0012 | 1801 | −.02184 | .5703 | 759 | .00448 |
| 5100 | 9.0838 | 43.1153 | 44.8145 | 68.5318 | 17.6699 | 1768 | −0.02220 | 0.4170 | 744 | 0.00462 |
| 5200 | 9.0915 | 44.0240 | 45.7232 | 68.7082 | 17.3521 | 1737 | −.02284 | .2693 | 729 | .00475 |
| 5300 | 9.0991 | 44.9336 | 46.6328 | 68.8815 | 17.0472 | 1706 | −.02313 | .1270 | 714 | .00498 |
| 5400 | 9.1066 | 45.8438 | 47.5430 | 69.0516 | 16.7544 | 1677 | −.02361 | −.0102 | 700 | .00513 |
| 5500 | 9.1140 | 46.7549 | 48.4541 | 69.2188 | 16.4731 | 1648 | −.02389 | −.1426 | 686 | .00530 |
| 5600 | 9.1214 | 47.6666 | 49.3658 | 69.3831 | 16.2027 | 1620 | −0.02421 | −0.2704 | 673 | 0.00543 |
| 5700 | 9.1287 | 48.5791 | 50.2783 | 69.5446 | 15.9427 | 1594 | −.02453 | −.3939 | 661 | .00553 |
| 5800 | 9.1359 | 49.4924 | 51.1916 | 69.7034 | 15.6924 | 1568 | −.02486 | −.5134 | 648 | .00577 |
| 5900 | 9.1431 | 50.4063 | 52.1055 | 69.8596 | 15.4515 | 1543 | −.02507 | −.6290 | 637 | .00583 |
| 6000 | 9.1502 | 51.3210 | 53.0202 | 70.0134 | 15.2194 | -------- | -------- | −.7410 | -------- | -------- |

## TABLE XLII—THERMODYNAMIC PROPERTIES OF NO (GAS)

[Molecular weight, 30.008]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ $a$ | $b$ | $\log K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ $c$ | $d$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -------- | 0 | 23.3447 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.16 | 7.187 | 2.1942 | 25.5389 | 50.339 | 207.8039 | -------- | -------- | 84.8403 | -------- | -------- |
| 300 | 7.134 | 2.2068 | 25.5515 | 50.384 | 206.5399 | -------- | -------- | 84.2876 | -------- | -------- |
| 400 | 7.162 | 2.9208 | 26.2655 | 52.436 | 155.2832 | -------- | -------- | 61.8373 | -------- | -------- |
| 500 | 7.289 | 3.4440 | 26.7887 | 54.048 | 124.5125 | -------- | -------- | 48.3348 | -------- | -------- |
| 600 | 7.468 | 4.3812 | 27.7259 | 55.392 | 103.9835 | -------- | -------- | 39.3132 | -------- | -------- |
| 700 | 7.657 | 5.1366 | 28.4813 | 56.556 | 89.3049 | -------- | -------- | 32.8556 | -------- | -------- |
| 800 | 7.833 | 5.9096 | 29.2543 | 57.589 | 78.2839 | -------- | -------- | 28.0035 | -------- | -------- |
| 900 | 7.990 | 6.7005 | 30.0452 | 58.520 | 69.7015 | -------- | -------- | 24.2228 | -------- | -------- |
| 1000 | 8.126 | 7.5060 | 30.8507 | 59.3700 | 62.8276 | 6160 | 0.03020 | 21.1937 | 2707 | 0.02129 |
| 1100 | 8.243 | 8.3245 | 31.6692 | 60.1500 | 57.1974 | 5606 | 0.02567 | 18.7115 | 2465 | 0.01723 |
| 1200 | 8.342 | 9.1537 | 32.4984 | 60.8715 | 52.5009 | 5143 | .02155 | 16.6401 | 2262 | .01500 |
| 1300 | 8.426 | 9.9921 | 33.3368 | 61.5425 | 48.5232 | 4751 | .01873 | 14.8851 | 2090 | .01334 |
| 1400 | 8.498 | 10.8383 | 34.1830 | 62.1696 | 45.1109 | 4415 | .01637 | 13.3759 | 1943 | .01147 |
| 1500 | 8.560 | 11.6912 | 35.0359 | 62.7580 | 42.1512 | 4124 | .01410 | 12.0721 | 1815 | .01033 |
| 1600 | 8.614 | 12.5499 | 35.8946 | 63.3122 | 39.5596 | 3869 | 0.01232 | 10.9274 | 1703 | 0.00944 |
| 1700 | 8.660 | 13.4136 | 36.7583 | 63.8358 | 37.2714 | 3644 | .01086 | 9.9162 | 1604 | .00859 |
| 1800 | 8.702 | 14.2817 | 37.6264 | 64.3319 | 35.2361 | 3444 | .00937 | 9.0165 | 1516 | .00791 |
| 1900 | 8.738 | 15.1537 | 38.4984 | 64.8034 | 33.4141 | 3265 | .00830 | 8.2107 | 1437 | .00740 |
| 2000 | 8.771 | 16.0292 | 39.3739 | 65.2524 | 31.7733 | 3104 | .00711 | 7.4848 | 1367 | .00645 |
| 2100 | 8.801 | 16.9078 | 40.2525 | 65.6811 | 30.2881 | 2958 | 0.00616 | 6.8274 | 1302 | 0.00628 |
| 2200 | 8.828 | 17.7892 | 41.1339 | 66.0912 | 28.9374 | 2826 | .00520 | 6.2293 | 1244 | .00583 |
| 2300 | 8.852 | 18.6732 | 42.0179 | 66.4841 | 27.7035 | 2704 | .00473 | 5.6826 | 1191 | .00525 |
| 2400 | 8.874 | 19.5595 | 42.9042 | 66.8613 | 26.5721 | 2593 | .00410 | 5.1811 | 1142 | .00500 |
| 2500 | 8.895 | 20.4480 | 43.7927 | 67.2240 | 25.5308 | 2491 | .00332 | 4.7193 | 1097 | .00468 |
| 2600 | 8.914 | 21.3384 | 44.6831 | 67.5732 | 24.5694 | 2393 | 0.00235 | 4.2927 | 1056 | 0.00429 |
| 2700 | 8.932 | 22.2307 | 45.5754 | 67.9100 | 23.6789 | 2311 | .00154 | 3.8973 | 1017 | .00419 |
| 2800 | 8.949 | 23.1248 | 46.4695 | 68.2351 | 22.8520 | 2230 | .00103 | 3.5299 | 981 | .00412 |
| 2900 | 8.966 | 24.0205 | 47.3652 | 68.5494 | 22.0820 | 2156 | .00013 | 3.1875 | 948 | .00390 |
| 3000 | 8.981 | 24.9179 | 48.2626 | 68.8537 | 21.3632 | 2086 | −.00060 | 2.8677 | 910 | .00392 |
| 3100 | 8.996 | 25.8167 | 49.1614 | 69.1484 | 20.6909 | 2021 | −0.00136 | 2.5683 | 887 | 0.00371 |
| 3200 | 9.010 | 26.7170 | 50.0617 | 69.4342 | 20.0607 | 1961 | −.00224 | 2.2874 | 860 | .00360 |
| 3300 | 9.024 | 27.6187 | 50.9634 | 69.7117 | 19.4687 | 1904 | −.00310 | 2.0233 | 834 | .00351 |
| 3400 | 9.037 | 28.5218 | 51.8665 | 69.9813 | 18.9118 | 1851 | −.00386 | 1.7745 | 810 | .00337 |
| 3500 | 9.049 | 29.4261 | 52.7708 | 70.2434 | 18.3868 | 1800 | −.00450 | 1.5397 | 787 | .00329 |
| 3600 | 9.061 | 30.3316 | 53.6763 | 70.4985 | 17.8913 | 1753 | −.00528 | 1.3178 | 765 | 0.00334 |
| 3700 | 9.073 | 31.2383 | 54.5830 | 70.7469 | 17.4228 | 1708 | −.00597 | 1.1077 | 745 | .00315 |
| 3800 | 9.085 | 32.1462 | 55.4909 | 70.9891 | 16.9793 | 1666 | −.00668 | .9085 | 725 | .00320 |
| 3900 | 9.096 | 33.0552 | 56.3999 | 71.2252 | 16.5588 | 1626 | −.00740 | .7194 | 707 | .00315 |
| 4000 | 9.107 | 33.9654 | 57.3101 | 71.4556 | 16.1597 | 1588 | −.00812 | .5395 | 689 | .00325 |
| 4100 | 9.118 | 34.8706 | 58.2213 | 71.6806 | 15.7805 | 1552 | −0.00872 | 0.3682 | 672 | 0.00320 |
| 4200 | 9.128 | 35.7889 | 59.1336 | 71.9005 | 15.4197 | 1518 | −.00952 | .2050 | 656 | .00324 |
| 4300 | 9.138 | 36.7022 | 60.0469 | 72.1154 | 15.0762 | 1485 | −.01000 | .0492 | 641 | .00322 |
| 4400 | 9.148 | 37.6165 | 60.9612 | 72.3256 | 14.7487 | 1453 | −.01039 | −.0997 | 627 | .00317 |
| 4500 | 9.158 | 38.5318 | 61.8765 | 72.5312 | 14.4362 | 1422 | −.01063 | −.2422 | 612 | .00326 |
| 4600 | 9.168 | 39.4481 | 62.7928 | 72.7326 | 14.1377 | 1393 | −0.01108 | −0.3785 | 599 | 0.00326 |
| 4700 | 9.178 | 40.3654 | 63.7101 | 72.9299 | 13.8524 | 1365 | −.01148 | −.5092 | 586 | .00332 |
| 4800 | 9.188 | 41.2837 | 64.6284 | 73.1232 | 13.5795 | 1338 | −.01176 | −.6346 | 574 | .00336 |
| 4900 | 9.198 | 42.2030 | 65.5477 | 73.3128 | 13.3182 | 1313 | −.01220 | −.7561 | 561 | .00350 |
| 5000 | 9.208 | 43.1233 | 66.4680 | 73.4987 | 13.0678 | 1288 | −.01255 | −.8708 | 550 | .00356 |
| 5100 | 9.218 | 44.0446 | 67.3893 | 73.6812 | 12.8278 | 1264 | −0.01268 | −0.9822 | 539 | 0.00355 |
| 5200 | 9.227 | 44.9669 | 68.3116 | 73.8602 | 12.5974 | 1240 | −.01276 | −1.0894 | 528 | .00368 |
| 5300 | 9.237 | 45.8901 | 69.2348 | 74.0361 | 12.3762 | 1218 | −.01306 | −1.1927 | 517 | .00380 |
| 5400 | 9.246 | 46.8142 | 70.1589 | 74.2088 | 12.1637 | 1196 | −.01315 | −1.2923 | 507 | .00392 |
| 5500 | 9.256 | 47.7393 | 71.0840 | 74.3786 | 11.9594 | 1175 | −.01332 | −1.3884 | 497 | .00405 |
| 5600 | 9.266 | 48.6654 | 72.0101 | 74.5454 | 11.7629 | 1155 | −0.01353 | −1.4812 | 488 | 0.00409 |
| 5700 | 9.275 | 49.5925 | 72.9372 | 74.7095 | 11.5738 | 1136 | −.01366 | −1.5709 | 478 | .00429 |
| 5800 | 9.285 | 50.5205 | 73.8652 | 74.8709 | 11.3916 | 1117 | −.01382 | −1.6576 | 469 | .00441 |
| 5900 | 9.294 | 51.4494 | 74.7941 | 75.0297 | 11.2161 | 1099 | −.01397 | −1.7415 | 461 | .00447 |
| 6000 | 9.304 | 52.3793 | 75.7240 | 75.1860 | 11.0469 | -------- | -------- | −1.8228 | -------- | -------- |

TABLE XLIII—THERMODYNAMIC PROPERTIES OF O (GAS)

[Atomic weight, 16.0000]

| $T$ (°K) | $C^\circ_p$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H^\circ_T - H^\circ_0$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H^\circ_T$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S^\circ_T$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ |
|---|---|---|---|---|
| 0 | ---------- | 0 | 59.6041 | ---------- |
| 298.16 | 5.2364 | 1.6074 | 61.2115 | 38.4689 |
| 300 | 5.2338 | 1.6170 | 61.2211 | 38.5010 |
| 400 | 5.1341 | 2.1349 | 61.7390 | 39.9915 |
| 500 | 5.0802 | 2.6454 | 62.2495 | 41.1308 |
| 600 | 5.0486 | 3.1517 | 62.7558 | 42.0540 |
| 700 | 5.0284 | 3.6555 | 63.2596 | 42.8307 |
| 800 | 5.0150 | 4.1576 | 63.7617 | 43.5011 |
| 900 | 5.0055 | 4.6587 | 64.2628 | 44.0914 |
| 1000 | 4.9988 | 5.1588 | 64.7629 | 44.6183 |
| 1100 | 4.9936 | 5.6584 | 65.2625 | 45.0945 |
| 1200 | 4.9894 | 6.3576 | 65.7617 | 45.5288 |
| 1300 | 4.9864 | 6.6564 | 66.2605 | 45.9281 |
| 1400 | 4.9838 | 7.1549 | 66.7590 | 46.2975 |
| 1500 | 4.9819 | 7.6532 | 67.2573 | 46.6413 |
| 1600 | 4.9805 | 8.1513 | 67.7554 | 46.9628 |
| 1700 | 4.9792 | 8.6493 | 68.2534 | 47.2646 |
| 1800 | 4.9784 | 9.1471 | 68.7512 | 47.5492 |
| 1900 | 4.9778 | 9.6450 | 69.2491 | 47.8184 |
| 2000 | 4.9776 | 10.1427 | 69.7468 | 48.0737 |
| 2100 | 4.9778 | 10.6405 | 70.2446 | 48.3166 |
| 2200 | 4.9784 | 11.1383 | 70.7424 | 48.5481 |
| 2300 | 4.9796 | 11.6362 | 71.2408 | 48.7695 |
| 2400 | 4.9812 | 12.1343 | 71.7384 | 48.9814 |
| 2500 | 4.9834 | 12.6325 | 72.2366 | 49.1848 |
| 2600 | 4.9862 | 13.1310 | 72.7351 | 49.3803 |
| 2700 | 4.9897 | 13.6298 | 73.2339 | 49.5686 |
| 2800 | 4.9935 | 14.1289 | 73.7330 | 49.7501 |
| 2900 | 4.9986 | 14.6285 | 74.2326 | 49.9254 |
| 3000 | 5.0041 | 15.1287 | 74.7328 | 50.0950 |
| 3100 | 5.0102 | 15.6294 | 75.2335 | 50.2592 |
| 3200 | 5.0170 | 16.1307 | 75.7348 | 50.4183 |
| 3300 | 5.0245 | 16.6328 | 76.2369 | 50.5728 |
| 3400 | 5.0325 | 17.1357 | 76.7398 | 50.7229 |
| 3500 | 5.0411 | 17.6393 | 77.2434 | 50.8689 |
| 3600 | 5.0502 | 18.1439 | 77.7480 | 51.0111 |
| 3700 | 5.0599 | 18.6494 | 78.2535 | 51.1496 |
| 3800 | 5.0700 | 19.1559 | 78.7600 | 51.2846 |
| 3900 | 5.0805 | 19.6634 | 79.2675 | 51.4165 |
| 4000 | 5.0914 | 20.1720 | 79.7761 | 51.5452 |
| 4100 | 5.1026 | 20.6817 | 80.2858 | 51.6711 |
| 4200 | 5.1140 | 21.1925 | 80.7966 | 51.7942 |
| 4300 | 5.1257 | 21.7045 | 81.3086 | 51.9147 |
| 4400 | 5.1375 | 22.2177 | 81.8218 | 52.0326 |
| 4500 | 5.1495 | 22.7320 | 82.3361 | 52.1482 |
| 4600 | 5.1616 | 23.2476 | 82.8517 | 52.2615 |
| 4700 | 5.1738 | 23.7644 | 83.3685 | 52.3727 |
| 4800 | 5.1860 | 24.2824 | 83.8865 | 52.4817 |
| 4900 | 5.1981 | 24.8016 | 84.4057 | 52.5888 |
| 5000 | 5.2102 | 25.3220 | 84.9261 | 52.6939 |
| 5100 | 5.2223 | 25.8436 | 85.4477 | 52.7972 |
| 5200 | 5.2344 | 26.3664 | 85.9705 | 52.8988 |
| 5300 | 5.2464 | 26.8905 | 86.4946 | 52.9986 |
| 5400 | 5.2583 | 27.4157 | 87.0198 | 53.0968 |
| 5500 | 5.2701 | 27.9421 | 87.5462 | 53.1933 |
| 5600 | 5.2818 | 28.4697 | 88.0738 | 53.2884 |
| 5700 | 5.2933 | 28.9985 | 88.6026 | 53.3820 |
| 5800 | 5.3047 | 29.5284 | 89.1325 | 53.4742 |
| 5900 | 5.3159 | 30.0594 | 89.6635 | 53.5649 |
| 6000 | 5.3270 | 30.5916 | 90.1957 | 53.6544 |

## TABLE XLIV—THERMODYNAMIC PROPERTIES OF $O_2$ (GAS)

[Molecular weight, 32.0000]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $-\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | ---------- | 0 | 2.0362 | ---------- | ---------- | -------- | ---------- | ---------- | -------- | ---------- |
| 298.16 | 7.021 | 2.0747 | 4.1109 | 49.011 | 199.6835 | -------- | ---------- | 80.6182 | -------- | ---------- |
| 300 | 7.023 | 2.0876 | 4.1238 | 49.056 | 198.4695 | -------- | ---------- | 80.0867 | -------- | ---------- |
| 400 | 7.196 | 2.7977 | 4.8339 | 51.098 | 149.2619 | -------- | ---------- | 58.5109 | -------- | ---------- |
| 500 | 7.431 | 3.5288 | 5.5650 | 52.728 | 119.7013 | -------- | ---------- | 45.5311 | -------- | ---------- |
| 600 | 7.670 | 4.2841 | 6.3203 | 54.105 | 99.9669 | -------- | ---------- | 36.8580 | -------- | ---------- |
| 700 | 7.883 | 5.0620 | 7.0982 | 55.303 | 85.8510 | -------- | ---------- | 30.6499 | -------- | ---------- |
| 800 | 8.063 | 5.8596 | 7.8958 | 56.368 | 75.2496 | -------- | ---------- | 25.9854 | -------- | ---------- |
| 900 | 8.212 | 6.6737 | 8.7099 | 57.327 | 66.9937 | -------- | ---------- | 22.3515 | -------- | ---------- |
| 1000 | 8.336 | 7.5012 | 9.5374 | 58.1990 | 60.3812 | 5926 | 0.02853 | 19.4400 | 2604 | 0.01823 |
| 1100 | 8.439 | 8.3400 | 10.3762 | 58.9983 | 54.9654 | 5392 | 0.02417 | 17.0545 | 2370 | 0.01550 |
| 1200 | 8.527 | 9.1883 | 11.2245 | 59.7364 | 50.4479 | 4947 | .02061 | 15.0640 | 2173 | .01322 |
| 1300 | 8.604 | 10.0448 | 12.0810 | 60.4220 | 46.6219 | 4569 | .01873 | 13.3777 | 2009 | .01200 |
| 1400 | 8.674 | 10.9087 | 12.9449 | 61.0622 | 43.3306 | 4245 | .01700 | 11.9307 | 1867 | .01083 |
| 1500 | 8.738 | 11.7793 | 13.8155 | 61.6628 | 40.4926 | 3963 | .01642 | 10.6752 | 1744 | .00960 |
| 1600 | 8.800 | 12.6562 | 14.6924 | 62.2287 | 37.9993 | 3717 | 0.01523 | 9.5756 | 1637 | 0.00826 |
| 1700 | 8.858 | 13.5391 | 15.5753 | 62.7640 | 35.7976 | 3499 | .01501 | 8.6044 | 1542 | .00743 |
| 1800 | 8.916 | 14.4278 | 16.4640 | 63.2719 | 33.8787 | 3305 | .01473 | 7.7403 | 1458 | .00643 |
| 1900 | 8.973 | 15.3223 | 17.3585 | 63.7555 | 32.0845 | 3132 | .01420 | 6.9665 | 1383 | .00550 |
| 2000 | 9.029 | 16.2224 | 18.2586 | 64.2172 | 30.5043 | 2976 | .01386 | 6.2695 | 1315 | .00491 |
| 2100 | 9.084 | 17.1280 | 19.1642 | 64.6590 | 29.0733 | 2835 | 0.01356 | 5.6384 | 1253 | 0.00455 |
| 2200 | 9.139 | 18.0392 | 20.0754 | 65.0829 | 27.7711 | 2707 | .01324 | 5.0643 | 1197 | .00407 |
| 2300 | 9.194 | 18.9558 | 20.9920 | 65.4904 | 26.5809 | 2590 | .01283 | 4.5398 | 1146 | .00370 |
| 2400 | 9.248 | 19.8779 | 21.9141 | 65.8828 | 25.4889 | 2484 | .01200 | 4.0586 | 1099 | .00330 |
| 2500 | 9.301 | 20.8054 | 22.8416 | 66.2614 | 24.4833 | 2386 | .01161 | 3.6157 | 1056 | .00295 |
| 2600 | 9.354 | 21.7381 | 23.7743 | 66.6272 | 23.5540 | 2295 | 0.01120 | 3.2066 | 1016 | 0.00260 |
| 2700 | 9.405 | 22.6761 | 24.7123 | 66.9812 | 22.6928 | 2212 | .01060 | 2.8277 | 980 | .00210 |
| 2800 | 9.455 | 23.6191 | 25.6553 | 67.3241 | 21.8922 | 2135 | .00979 | 2.4756 | 945 | .00204 |
| 2900 | 9.503 | 24.5670 | 26.6032 | 67.6568 | 21.1462 | 2063 | .00913 | 2.1477 | 913 | .00187 |
| 3000 | 9.551 | 25.5197 | 27.5559 | 67.9797 | 20.4494 | 1997 | .00831 | 1.8415 | 883 | .00166 |
| 3100 | 9.596 | 26.4770 | 28.5132 | 68.2936 | 19.7969 | 1935 | 0.00761 | 1.5550 | 855 | 0.00161 |
| 3200 | 9.640 | 27.4388 | 29.4750 | 68.5990 | 19.1846 | 1877 | .00671 | 1.2862 | 829 | .00129 |
| 3300 | 9.682 | 28.4049 | 30.4411 | 68.8963 | 18.6091 | 1822 | .00622 | 1.0337 | 804 | .00123 |
| 3400 | 9.723 | 29.3752 | 31.4114 | 69.1859 | 18.0670 | 1771 | .00540 | .7960 | 781 | .00106 |
| 3500 | 9.762 | 30.3494 | 32.3856 | 69.4683 | 17.5556 | 1723 | .00469 | .5718 | 759 | .00097 |
| 3600 | 9.799 | 31.3275 | 33.3637 | 69.7439 | 17.0723 | 1677 | 0.00426 | 0.3600 | 739 | 0.00077 |
| 3700 | 9.835 | 32.3092 | 34.3454 | 70.0128 | 16.6148 | 1634 | .00350 | .1595 | 719 | .00069 |
| 3800 | 9.869 | 33.2944 | 35.3306 | 70.2756 | 16.1813 | 1594 | .00278 | −.0304 | 700 | .00071 |
| 3900 | 9.901 | 34.2829 | 36.3191 | 70.5323 | 15.7698 | 1555 | .00225 | −.2106 | 682 | .00070 |
| 4000 | 9.932 | 35.2745 | 37.3107 | 70.7834 | 15.3788 | 1519 | .00161 | −.3818 | 665 | .00070 |
| 4100 | 9.960 | 36.2691 | 38.3053 | 71.0290 | 15.0067 | 1484 | 0.00107 | −0.5447 | 649 | 0.00068 |
| 4200 | 9.987 | 37.2665 | 39.3027 | 71.2698 | 14.6523 | 1450 | .00069 | −.6999 | 634 | .00056 |
| 4300 | 10.013 | 38.2665 | 40.3027 | 71.5046 | 14.3144 | 1419 | .00010 | −.8479 | 619 | .00062 |
| 4400 | 10.037 | 39.2690 | 41.3052 | 71.7351 | 13.9918 | 1388 | −.00014 | −.9892 | 606 | .00043 |
| 4500 | 10.060 | 40.2738 | 42.3100 | 71.9609 | 13.6835 | 1359 | −.00063 | −1.1243 | 592 | .00050 |
| 4600 | 10.081 | 41.2809 | 43.3171 | 72.1822 | 13.3887 | 1331 | −0.00089 | −1.2535 | 579 | 0.00051 |
| 4700 | 10.103 | 42.2901 | 44.3263 | 72.3993 | 13.1064 | 1304 | −.00127 | −1.3772 | 567 | .00048 |
| 4800 | 10.121 | 43.3013 | 45.3375 | 72.6122 | 12.8360 | 1279 | −.00162 | −1.4958 | 555 | .00053 |
| 4900 | 10.139 | 44.3143 | 46.3505 | 72.8210 | 12.5766 | 1254 | −.00190 | −1.6096 | 543 | .00060 |
| 5000 | 10.156 | 45.3290 | 47.3652 | 73.0261 | 12.3277 | 1230 | −.00208 | −1.7188 | 533 | .00049 |
| 5100 | 10.172 | 46.3454 | 48.3816 | 73.2278 | 12.0886 | 1207 | −0.00232 | −1.8238 | 522 | 0.00062 |
| 5200 | 10.187 | 47.3634 | 49.3996 | 73.4250 | 11.8588 | 1184 | −.00240 | −1.9248 | 512 | .00060 |
| 5300 | 10.201 | 48.3828 | 50.4190 | 73.6192 | 11.6378 | 1162 | −.00248 | −2.0220 | 502 | .00064 |
| 5400 | 10.215 | 49.4036 | 51.4398 | 73.8100 | 11.4251 | 1143 | −.00282 | −2.1156 | 493 | .00056 |
| 5500 | 10.228 | 50.4257 | 52.4619 | 73.9975 | 11.2201 | 1122 | −.00286 | −2.2058 | 484 | .00057 |
| 5600 | 10.239 | 51.4496 | 53.4858 | 74.1819 | 11.0226 | 1102 | −0.00293 | −2.2928 | 475 | 0.00067 |
| 5700 | 10.250 | 52.4735 | 54.5097 | 74.3632 | 10.8322 | 1084 | −.00310 | −2.3768 | 466 | .00076 |
| 5800 | 10.261 | 53.4991 | 55.5353 | 74.5416 | 10.6483 | 1067 | −.00335 | −2.4579 | 458 | .00077 |
| 5900 | 10.270 | 54.5256 | 56.5618 | 74.7171 | 10.4709 | 1049 | −.00343 | −2.5363 | 450 | .00080 |
| 6000 | 10.279 | 55.5581 | 57.5893 | 74.8898 | 10.2995 | -------- | ---------- | −2.6121 | -------- | ---------- |

## TABLE XLV—THERMODYNAMIC PROPERTIES OF OH (GAS)

[Molecular weight, 17.008]

| $T$ (°K) | $C_p^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $H_T^\circ - H_0^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $H_T^\circ$ $\left(\frac{\text{kcal}}{\text{mole}}\right)$ | $S_T^\circ$ $\left(\frac{\text{cal}}{\text{mole °K}}\right)$ | $\frac{\Delta H^\circ}{RT}$ | $\delta\left(-\frac{\Delta H^\circ}{RT}\right)=\frac{-\delta T}{100}\left(\frac{a}{T}+b\right)$ | | log $K$ | $\delta \log K=\frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $a$ | $b$ | | $c$ | $d$ |
| 0 | -------- | 0 | 44.7266 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| 298.16 | 7.141 | 2.1062 | 46.8323 | 43.888 | 170.7827 | -------- | -------- | 69.3677 | -------- | -------- |
| 300 | 7.139 | 2.1225 | 46.8491 | 43.934 | 169.7395 | -------- | -------- | 68.9110 | -------- | -------- |
| 400 | 7.074 | 2.8296 | 47.5562 | 45.978 | 127.6916 | -------- | -------- | 50.4585 | -------- | -------- |
| 500 | 7.048 | 3.5350 | 48.2616 | 47.553 | 102.4572 | -------- | -------- | 39.3522 | -------- | -------- |
| 600 | 7.053 | 4.2408 | 48.9674 | 48.840 | 85.6303 | -------- | -------- | 31.9260 | -------- | -------- |
| 700 | 7.087 | 4.9469 | 49.6735 | 49.927 | 73.6091 | -------- | -------- | 26.6057 | -------- | -------- |
| 800 | 7.150 | 5.6584 | 50.3850 | 50.877 | 64.5588 | -------- | -------- | 22.6043 | -------- | -------- |
| 900 | 7.234 | 6.3774 | 51.1040 | 51.723 | 57.5682 | -------- | -------- | 19.4833 | -------- | -------- |
| 1000 | 7.333 | 7.1060 | 51.8326 | 52.4910 | 51.9464 | 5034 | 0.02814 | 16.9801 | 2227 | 0.02885 |
| 1100 | 7.440 | 7.8446 | 52.5712 | 53.1949 | 47.3419 | 4575 | 0.02930 | 14.9267 | 2029 | 0.02457 |
| 1200 | 7.551 | 8.5942 | 53.3208 | 53.8470 | 43.5001 | 4194 | 0.02915 | 13.2113 | 1863 | .02172 |
| 1300 | 7.663 | 9.3549 | 54.0815 | 54.4559 | 40.2448 | 3873 | .02777 | 11.7565 | 1723 | .01909 |
| 1400 | 7.772 | 10.1266 | 54.8532 | 55.0278 | 37.4506 | 3599 | .02607 | 10.5067 | 1603 | .01678 |
| 1500 | 7.875 | 10.9090 | 55.6356 | 55.5675 | 35.0252 | 3361 | .02478 | 9.4213 | 1498 | .01535 |
| 1600 | 7.973 | 11.7014 | 56.4280 | 56.0758 | 32.8998 | 3153 | 0.02340 | 8.4697 | 1407 | 0.01355 |
| 1700 | 8.066 | 12.5033 | 57.2299 | 56.5650 | 31.0217 | 2970 | .02210 | 7.6285 | 1327 | .01198 |
| 1800 | 8.152 | 13.3142 | 58.0408 | 57.0285 | 29.3496 | 2808 | .02041 | 6.8793 | 1255 | .01087 |
| 1900 | 8.233 | 14.1335 | 58.8601 | 57.4714 | 27.8513 | 2663 | .01890 | 6.2079 | 1190 | .01020 |
| 2000 | 8.308 | 14.9605 | 59.6871 | 57.8956 | 26.5009 | 2533 | .01731 | 5.6027 | 1133 | .00898 |
| 2100 | 8.378 | 15.7948 | 60.5214 | 58.3027 | 25.2774 | 2415 | 0.01617 | 5.0542 | 1080 | 0.00839 |
| 2200 | 8.443 | 16.6359 | 61.3625 | 58.6939 | 24.1635 | 2308 | .01452 | 4.5549 | 1032 | .00790 |
| 2300 | 8.504 | 17.4832 | 62.2098 | 59.0705 | 23.1452 | 2210 | .01387 | 4.0983 | 989 | .00702 |
| 2400 | 8.561 | 18.3365 | 63.0631 | 59.4337 | 22.2105 | 2121 | .01260 | 3.6792 | 949 | .00650 |
| 2500 | 8.614 | 19.1952 | 63.9218 | 59.7842 | 21.3495 | 2038 | .01185 | 3.2931 | 912 | .00603 |
| 2600 | 8.663 | 20.0591 | 64.7857 | 60.1230 | 20.5538 | 1962 | 0.01093 | 2.9363 | 878 | 0.00561 |
| 2700 | 8.710 | 20.9277 | 65.6543 | 60.4508 | 19.8162 | 1892 | .00999 | 2.6055 | 846 | .00546 |
| 2800 | 8.755 | 21.8010 | 66.5276 | 60.7684 | 19.1305 | 1826 | .00934 | 2.2979 | 817 | .00458 |
| 2900 | 8.798 | 22.6786 | 67.4052 | 61.0764 | 18.4915 | 1765 | .00877 | 2.0113 | 790 | .00457 |
| 3000 | 8.838 | 23.5604 | 68.2870 | 61.3753 | 17.8944 | 1708 | .00813 | 1.7434 | 764 | .00435 |
| 3100 | 8.877 | 24.4462 | 69.1728 | 61.6658 | 17.3358 | 1655 | 0.00741 | 1.4926 | 740 | 0.00415 |
| 3200 | 8.913 | 25.3357 | 70.0623 | 61.9482 | 16.8107 | 1605 | .00694 | 1.2572 | 718 | .00372 |
| 3300 | 8.949 | 26.2288 | 70.9554 | 62.2230 | 16.3174 | 1558 | .00646 | 1.0359 | 697 | .00360 |
| 3400 | 8.982 | 27.1253 | 71.8519 | 62.4906 | 15.8527 | 1513 | .00621 | .8273 | 677 | .00327 |
| 3500 | 9.015 | 28.0252 | 72.7518 | 62.7515 | 15.4142 | 1471 | .00579 | .6306 | 659 | .00304 |
| 3600 | 9.047 | 28.9283 | 73.6549 | 63.0059 | 14.9998 | 1432 | 0.00527 | 0.4445 | 641 | 0.00286 |
| 3700 | 9.077 | 29.8345 | 74.5611 | 63.2542 | 14.6075 | 1395 | .00489 | .2684 | 624 | .00279 |
| 3800 | 9.107 | 30.7437 | 75.4703 | 63.4966 | 14.2355 | 1359 | .00464 | .1014 | 608 | .00270 |
| 3900 | 9.135 | 31.6558 | 76.3824 | 63.7336 | 13.8824 | 1325 | .00435 | −.0572 | 593 | .00255 |
| 4000 | 9.162 | 32.5706 | 77.2972 | 63.9652 | 13.5468 | 1293 | .00413 | −.2080 | 579 | .00238 |
| 4100 | 9.189 | 33.4882 | 78.2148 | 64.1917 | 13.2273 | 1263 | 0.00379 | −0.3516 | 565 | 0.00228 |
| 4200 | 9.215 | 34.4084 | 79.1350 | 64.4135 | 12.9228 | 1234 | .00352 | −.4884 | 552 | .00223 |
| 4300 | 9.241 | 35.3312 | 80.0578 | 64.6306 | 12.6323 | 1206 | .00331 | −.6190 | 539 | .00220 |
| 4400 | 9.266 | 36.2565 | 80.9831 | 64.8434 | 12.3549 | 1179 | .00320 | −.7437 | 528 | .00197 |
| 4500 | 9.290 | 37.1843 | 81.9109 | 65.0518 | 12.0897 | 1154 | .00303 | −.8630 | 517 | .00181 |
| 4600 | 9.314 | 38.1145 | 82.8411 | 65.2563 | 11.8358 | 1129 | 0.00289 | −0.9772 | 506 | 0.00174 |
| 4700 | 9.338 | 39.0471 | 83.7737 | 65.4569 | 11.5927 | 1106 | .00268 | −1.0866 | 495 | .00178 |
| 4800 | 9.362 | 39.9821 | 84.7087 | 65.6537 | 11.3596 | 1084 | .00253 | −1.1915 | 485 | .00172 |
| 4900 | 9.384 | 40.9194 | 85.6460 | 65.8470 | 11.1358 | 1062 | .00250 | −1.2922 | 476 | .00160 |
| 5000 | 9.406 | 41.8589 | 86.5855 | 66.0368 | 10.9209 | 1041 | .00248 | −1.3890 | 466 | .00163 |
| 5100 | 9.427 | 42.8006 | 87.5272 | 66.2233 | 10.7143 | 1021 | 0.00235 | −1.4820 | 458 | 0.00152 |
| 5200 | 9.448 | 43.7443 | 88.4709 | 66.4065 | 10.5156 | 1002 | .00214 | −1.5716 | 449 | .00148 |
| 5300 | 9.469 | 44.6902 | 89.4168 | 66.5867 | 10.3244 | 984 | .00208 | −1.6578 | 440 | .00152 |
| 5400 | 9.489 | 45.6381 | 90.3647 | 66.7639 | 10.1401 | 966 | .00206 | −1.7408 | 433 | .00137 |
| 5500 | 9.509 | 46.5880 | 91.3146 | 66.9352 | 9.9624 | 949 | .00194 | −1.8209 | 425 | .00141 |
| 5600 | 9.529 | 47.5399 | 92.2665 | 67.1097 | 9.7910 | 932 | 0.00189 | −1.8982 | 418 | 0.00127 |
| 5700 | 9.548 | 48.4937 | 93.2203 | 67.2785 | 9.6256 | 916 | .00187 | −1.9728 | 411 | .00124 |
| 5800 | 9.567 | 49.4495 | 94.1761 | 67.4447 | 9.4658 | 901 | .00179 | −2.0449 | 404 | .00123 |
| 5900 | 9.585 | 50.4071 | 95.1337 | 67.6084 | 9.3113 | 886 | .00163 | −2.1146 | 397 | .00123 |
| 6000 | 9.603 | 51.3665 | 96.0931 | 67.7697 | 9.1620 | -------- | -------- | −2.1820 | -------- | -------- |