

REPORT 1037

GENERAL METHOD AND THERMODYNAMIC TABLES FOR COMPUTATION OF EQUILIBRIUM COMPOSITION AND TEMPERATURE OF CHEMICAL REACTIONS¹

By VEARL N. HUFF, SANFORD GORDON, and VIRGINIA E. MORRELL

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 proc-

ess 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° , sensible enthalpy $H_T^\circ - H_0^\circ$, and molar entropy S_T° 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° , $H_T^\circ - H_0^\circ$, and S_T° , assigned values of enthalpy H_T° 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:

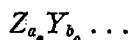
(1) Estimates of composition and temperature are made and used in simple equations to compute the values of error parameters, which indicate inconsistency among the estimates of composition and temperature. (These estimates need not be based on previous experience, but for rapid convergence it is desirable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

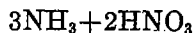
(3) The new composition is used to compute new values of the error parameters and step (2) is repeated until the desired accuracy is obtained.

EQUATIONS FOR DISSOCIATION, MASS, PRESSURE, AND VOLUME

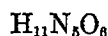
The substances entering a reaction process will be designated the reactants and can be represented by the equivalent formula



where the subscripts a_0, b_0, \dots are proportional to the total number of atoms of the elements Z, Y, \dots , 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

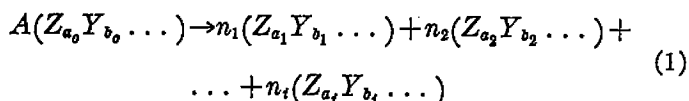


An equivalent formula would be



where the atoms hydrogen, nitrogen, and oxygen, may be represented by Z, Y , and X , respectively, and 11, 5, and 6 by a_0, b_0 , and c_0 , respectively. The weight of the equivalent formula M , 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



where n_i is the number of moles of the i th molecule or atom. The subscripts a_i, b_i, \dots , which can take on only positive

integral values or zero, denote the number of Z, Y, \dots 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

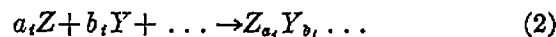
$$p_i = n_i$$

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



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

$$K_i = \frac{p_i}{p_z^{a_i} p_y^{b_i} \dots} \quad (3)$$

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

$$K_i = \frac{1}{p_z^{a_i} p_y^{b_i} \dots} \quad (4)$$

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

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

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

$$\delta_i = \log p_i - a_i \log p_z - b_i \log p_y - \dots - \log K_i \quad (6)$$

and for liquid or solid molecules

$$\delta_i = -a_i \log p_z - b_i \log p_r - \dots - \log K_i \quad (7)$$

where K_i is defined by equation (5). The value of each δ_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, δ_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.

$$\begin{aligned} a &= \frac{1}{A} \sum_i a_i n_i \\ b &= \frac{1}{A} \sum_i b_i n_i \\ &\dots = \dots \end{aligned} \quad (8)$$

where a, b, \dots are the number of gram atoms of substance Z, Y, \dots per equivalent formula required to form the products of reaction. A trial composition generally leads to values of a, b, \dots that differ from the desired values of a_o, b_o, \dots 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

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

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 ρ is defined as

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

For a reaction process with an assigned density, the value of ρ must approach the assigned value ρ_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° 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 $Z_{a_o} Y_{b_o} \dots$ is denoted by h_o and is given by the expression

$$h_o = n_f (H_T^\circ)_f + n_o (H_T^\circ)_o \quad (11)$$

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

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

where C_p° is the molar specific heat at constant pressure, and H_0° is the chemical energy of the substance at a temperature of $0^\circ K$. Values of H_T° 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

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

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 ΔQ_1 and ΔQ_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 δ_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

$$x_i - a_i x_z - b_i x_y - \dots - q_i x_T = -\delta_i \quad (13)$$

For solid or liquid products

$$-a_i x_z - b_i x_y - \dots - q_i x_T = -\delta_i \quad (14)$$

For all products

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

$$\sum_i b_i n_i x_i - A b x_A = \delta_b \quad (15)$$

$$\dots = \dots$$

$$\sum_i p_i x_i = \delta_p \quad (16)$$

$$\sum_i h_i' x_i - A h x_A + T C' x_T = \delta_h \quad (17)$$

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

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

$$x_z, x_y, \dots = x_i \text{ for atoms}$$

$$x_A = \Delta \log A$$

$$x_T = \Delta \log T$$

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

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

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

$$\dots = \dots$$

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

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

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

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

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

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

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

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			Const	
	x_1	x_2	...	x_x	x_r	...	x_N	x_A	x_r		
(13)	1	0	0	$-a_1$	$-\delta_1$	...	0	0	$-q_1$	$-\delta_1$	
	0	1	0	$-a_2$	$-\delta_2$	...	0	0	$-q_2$	$-\delta_2$	
	0	0	...	...	...	...	0	0	...	...
a	$a_1 n_1$	$a_2 n_2$	...	n_x	0	0	...	$a_N n_N$	$-Aa$	0	δ_a
b	$b_1 n_1$	$b_2 n_2$	...	0	n_r	0	...	$b_N n_N$	$-Ab$	0	δ_b
...	...	...	...	0	0	...	...	...	...	0	...
N	0	0	0	...	...	...	0	0	q_N	0	δ_N
P	p_1	p_2	...	p_x	p_r	0	0	0	0	0	δ_P
h	h_1'	h_2'	...	h_x'	h_r'	...	...	h_N'	$-Ah$	TC'	δ_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.

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

$$\left[\begin{array}{c|ccc} U_m & \alpha_1 & & \\ \hline & \alpha_2 & & \\ & & \alpha_3 & \end{array} \right] \quad (19)$$

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

$$\left[\begin{array}{c|ccc} U_m & \alpha_1 & & \\ \hline & \alpha_3 & & \\ & & \alpha_4 & \end{array} \right] \quad (20)$$

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

$$[\alpha_5] = [\alpha_3] - [\alpha_2][\alpha_1] \quad (21)$$

For computation, equation (21) is written

$$[\alpha_5] = [\alpha_2] \alpha_3 \left[\frac{-\alpha_1}{U_k} \right] \quad (22)$$

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 $[\alpha_4]$

	Gaseous molecules			Atoms			Solids or liquids			Const	
	x_1	x_2	...	x_x	x_r	...	x_N	x_A	x_r		
a	$a_1 n_1$	$a_2 n_2$	...	n_x	0	0	...	$a_N n_N$	$-Aa$	0	δ_a
b	$b_1 n_1$	$b_2 n_2$	...	0	n_r	0	...	$b_N n_N$	$-Ab$	0	δ_b
...	...	...	...	0	0	...	...	...	...	0	...
N	0	0	0	...	...	...	0	0	q_N	0	δ_N
P	p_1	p_2	...	p_x	p_r	...	0	0	0	0	δ_P
h	h_1'	h_2'	...	h_x'	h_r'	...	...	h_N'	$-Ah$	TC'	δ_h

(a) Submatrix $[\alpha_2 | \alpha_3]$ 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
N	0	0	0	0	0	0	0	0	1	0	0
	0	0	0	0	0	0	0	0	0	1	0
q	q_1	q_2	...	0	0	0	0	0	0	0	1
δ	δ_1	δ_2	...	0	0	0	0	0	0	0	1

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

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

is constructed from $[\alpha_5]$. The values of the variables x_{m+1}, \dots, 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

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

For illustration, the submatrices $[\alpha_1]$, $[\alpha_2]$, and $[\alpha_3]$ were taken from figure 1 and used to construct figure 2. The submatrix $[\alpha_2 | \alpha_3]$ 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)

$$x_A - x_T = \log \frac{\rho_0}{\rho} \quad (24)$$

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

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

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° 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.

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

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

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

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 fol-

lowing correction equation for entropy can be written from equation (27):

$$\sum s'_i x_i - A s x_A + C' x_T = \delta_s \quad (28)$$

where

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

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

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									
		(28)									
s	(28)	s'_1	s'_2	...	s'_n	$-A s$	C'	x_T			

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

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

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

$$dP = \sum_i d p_i \quad (30)$$

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

$$d\rho = \frac{M_r}{RT} dA - \frac{A M_r}{RT^2} dT \quad (31)$$

Then

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

Therefore

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

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 8.3144×10^7 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,

$$\frac{d \log p_i}{d \log T} - a_i \frac{d \log p_z}{d \log T} - b_i \frac{d \log p_r}{d \log T} - \dots - q_i = \frac{d \delta_i}{d \log T} \quad (33)$$

for liquid and solid products,

$$-a_i \frac{d \log p_z}{d \log T} - b_i \frac{d \log p_r}{d \log T} - \dots - q_i = \frac{d \delta_i}{d \log T} \quad (34)$$

and for all products of reaction,

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

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

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 δ_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:

$$C_p^0 = \frac{A}{n} \left(\frac{\partial h}{\partial T} \right)_p = \frac{1}{nT} \left[\sum_i (H_T^0)_i n_i \left(\frac{\partial \log n_i}{\partial \log T} \right)_p - Ah \left(\frac{\partial \log A}{\partial \log T} \right)_p + TC' \right] \quad (37)$$

	$-D_1$	$-D_2$	-----	$-D_z$	$-D_r$	-----	-----	$-D_N$	$-D_A$	
a	$a_1 n_1$	$a_2 n_2$	-----	0	0	0	0	$a_N n_N$	$-Aa$	0
b	$b_1 n_1$	$b_2 n_2$	-----	0	0	0	0	$b_N n_N$	$-Ab$	0
-----				0	0	0	0			0
N	0	0	0	a_N	b_N	-----	0	0	0	q_N
s	s_1'	s_2'	-----	s_z'	s_r'	-----	0	s_N'	$-As$	C'

(a) Submatrix $\begin{bmatrix} \alpha_2 \\ \alpha_3 \end{bmatrix}$.

a	a_1	a_2	-----	1	0	0	0	0	0	0
b	b_1	b_2	-----	0	1	0	0	0	0	0
-----				0	0	-----	0	0	0	0
N	0	0	0	0	0	0	0	1	0	0
q	q_1	q_2	-----	0	0	0	0	0	1	0

(b) Submatrix $\begin{bmatrix} -\alpha_1 \\ -\alpha_2 \end{bmatrix}$ transposed.

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

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

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

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^0 .

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

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

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

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

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

$$h^* = \frac{\sum_i (H_T^0)_i n_i}{A} + \frac{M^2 RT \sum_i p_i D_i}{2A(D_A - 1)} \quad (41)$$

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_c .

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

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

where

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

$$\delta_n^* = Ah^* \log \frac{h_c}{h^*}$$

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

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_N	x_T	...	x_A	x_T			
a	$a_1 n_1$	$a_2 n_1$	...	n_N	0	0	...	$a_N n_N$	$-Aa$	0	δ_a
b	$b_1 n_1$	$b_2 n_1$	...	0	n_T	0	...	$b_N n_N$	$-Ab$	0	δ_b
...	...	...	...	0	0	...	...	...	...	0	...
N	0	0	0	a_N	b_N	...	0	0	0	q_N	δ_N
S	s_1'	s_2'	...	s_N'	s_T'	...	s_A'	$-As$	C'		δ_s
h*	h_1''	h_2''	...	h_N''	h_T''	...	h_A''	$-Ah^*$	TC''		δ_{h^*}

(a) Submatrix $[a_i, a_j]$.

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
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	δ_1	δ_2	...	0	0	0	0	0	0	0	1

(b) Submatrix $[\frac{-a_i}{U_k}]$ transposed.

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

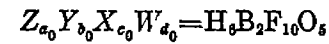
$$\frac{t}{m} = \frac{RT}{AM, u} \quad (43)$$

where m is the mass flow per second. If T is in degrees Kelvin and u is in centimeters per second, R equal to $\frac{82.0567 \text{ (cm}^3 \text{) (atm)}}{\text{(}^\circ\text{K) (mole)}}$ will give t/m in $\text{(cm}^2 \text{) (sec)/(gm)}$. 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

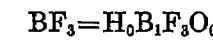
The calculation of equilibrium temperature and composition of the reaction of 1 mole of diborane (B_2H_6) with 5 moles of oxygen bifluoride (OF_2) is illustrated in this example for processes of

- (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



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

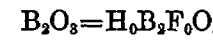
The following gaseous products will be considered as the products of reaction: boron trifluoride BF_3 , boron trioxide B_2O_3 , boron fluoride BF , boron hydride BH , boron oxide BO , diatomic boron B_2 , hydrogen H_2 , water vapor H_2O , hydroxyl radical OH , hydrogen fluoride HF , oxygen O_2 , fluorine 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:



and therefore

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

Similarly,



and

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

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

All values of a_i , b_i , c_i , and d_i 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

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

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

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

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

The values of a_i , b_i , c_i , d_i , 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_i 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_i , b_i , c_i and d_i 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 $q_i = \left(\frac{\Delta H}{RT}\right)_i$ 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 δ row of figure 6 (b) may be computed from equation (6) for gaseous products

$$\delta_i = \log p_i - a_i \log p_H - b_i \log p_B - c_i \log p_F - d_i \log p_O - \log K_i$$

The values of $\log K_i$ 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

$$\delta_i = -\log K_i$$

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

	Gaseous molecules												Atoms				Const		
	^a B ₂ F ₆	^a B ₂ O ₄	^a BF	^a BH	^a BO	^a B ₂	^a H ₂	^a H ₂ O	^a OH	^a HF	^a O ₂	^a F ₂	^a H	^a B	^a F	^a O			
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	1.000	0	2.000	0	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	2.384	2.629	3.569	2.527	5.720	.995	.577	.765	.320	.378	.960	1.051	3.177	.826	.794	-27.346	6.446	-13.125

(a) Submatrix $\left[\alpha_i \right]$.

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
q	-62.075	-80.693	-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	0.280	3.137	0	0	0	0	0	0	1

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

FIGURE 6.—Numerical example of submatrices of correction equations for adiabatic combustion of diborane and oxygen bifluoride after first estimate of n_i , 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 $0 \times 1.000 = 0$, $1 \times 1.000 = 1.000$, $3 \times 1.000 = 3.000$ and $0 \times 1.000 = 0$.

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 $(H_T^0)_i$ from tables of thermodynamic functions, in this case table I. For example, the entry in the first column is $72,172 \times 1.000 = 72,172$. All values in row **h** have been divided by 10^6 .

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 $T \sum_i (C_p^0)_i n_i$. The values of $(C_p^0)_i$ 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 δ_b , δ_c , δ_d , and δ_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	-240.897	-13.564
1.000	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 $[\alpha_i]$ obtained from matrix multiplication $[\alpha_i] [\alpha_j] \left[\frac{-\alpha_i}{U_k} \right]$.

12.000	0.08333	0.08333	0.2500	-0.6867	-10.656	0.1159
1.000	12.917	0.3032	0.5226	-0.6451	-21.035	-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 $[\alpha_j]$ (Crout's auxiliary matrix of $[\alpha_i]$).

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).

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

$$\delta_P = P \log \frac{P_0}{P}$$

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

The matrix multiplication $[\alpha_i] [\alpha_j] \left[\frac{-\alpha_i}{U_k} \right]$ will result in the matrix $[\alpha_k]$ 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 $[\alpha_k]$ 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

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

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

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

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

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 :

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

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

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 ϵ in the following table where ϵ 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	5	51.540	24.082	13.104	10.541	10.016	10.000	10.000
d	9	29.641	11.954	38.660	5.240	5.022	5.000	5.000
P	16	125.435	38.000	52.434	21.416	20.436	20.400	20.400
h	2734.615	12,055.015	2060.090	2009.960	965.968	912.388	905.594	905.534
ϵ	26.892	5.861	4.082	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 $^\circ\text{K}$ 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.

$$\begin{aligned} n_{\text{BF}_3} &= 0.1304 \\ n_{\text{HF}} &= 0.3503 \\ n_{\text{H}} &= 0.0867 \\ n_{\text{O}} &= 0.2544 \\ A &= 0.0815 \end{aligned}$$

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 ($p_i = n_i$)

$$\begin{aligned} 0 &= \log 0.3503 - \log 0.0867 - \log p_{\text{F}} - 1.8944 \\ \log p_{\text{F}} &= -0.45556 + 1.06198 - 1.8944 \\ &= -1.28798 \end{aligned}$$

$$p_{\text{F}} = 0.0515$$

Similarly, p_{B} can be estimated with the assumed values of p_{BF_3} and p_{F}

$$\begin{aligned} 0 &= \log 0.1304 - \log p_{\text{B}} - 3 \log 0.0515 - 5.6953 \\ \log p_{\text{B}} &= -0.88472 + 3.86394 - 5.6953 \\ p_{\text{B}} &= 0.0019 \end{aligned}$$

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

$$\begin{aligned} n_{\text{BF}_3} &= 0.1304 & n_{\text{OH}} &= 0.0150 \\ n_{\text{B}_2\text{O}_3} &= 0.0078 & n_{\text{HF}} &= 0.3503 \\ n_{\text{BF}} &= 0.0043 & n_{\text{O}_2} &= 0.0269 \\ n_{\text{BH}} &= 0 & n_{\text{F}_2} &= 0 \\ n_{\text{BO}} &= 0.0053 & n_{\text{H}} &= 0.0867 \\ n_{\text{B}_2} &= 0 & n_{\text{B}} &= 0.0019 \\ n_{\text{H}_2} &= 0.0029 & n_{\text{F}} &= 0.0515 \\ n_{\text{H}_2\text{O}} &= 0.0009 & n_{\text{O}} &= 0.2544 \\ A &= 0.0815 & T &= 4000^\circ\text{K} \end{aligned}$$

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

$$\begin{aligned} (s_{\text{BF}_3})' &= 0.1304 (105.951 - 1.98718 - 4.57565 \log 0.1304) \\ &= 14.0848 \end{aligned}$$

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 $\sum n_i(C_p^o)_i$. The values of $(C_p^o)_i$ are obtained from tables of thermodynamic data, in this case table I.

9. The value of δ_i is found in a manner similar to δ_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 $(H_T^o)_i$ 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

$$(h_{BF_3})'' = (h_{BF_3})' + \frac{M^2 R T p_{BF_3} D_{BF_3}}{2(D_A - 1)}$$

$$\frac{1 \times 1.98718 \times 4000 \times 1.000 \times 12.990}{2(19.039 - 1)} \text{ (cal)}$$

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

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

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					Const		
	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_T	x_O		x_A	x_T
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	-1.1675	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	0.0533	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	0.3859	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 $\begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix}$.

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	-18.603	-19.674	-15.913	-8.705	0	0	0	0	0	1	0
s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

(b) Submatrix $\begin{bmatrix} -\alpha_1 \\ -U_1 \end{bmatrix}$ 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						
	ΣBF_3	ΣB_2O_3	ΣBF	ΣBH	ΣBO	ΣB_2	ΣH_2	ΣH_2O	ΣOH	ΣHF	ΣO_2	ΣF_2	ΣB	ΣH	ΣF	ΣO	ΣA	ΣT	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	103.864	114.773	71.917	59.425	67.633	68.593	49.067	70.471	62.002	59.067	68.786	68.826	38.319	47.562	49.562	49.492	-1020.944	161.182	-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 $\begin{bmatrix} \alpha_1 & \alpha_2 \end{bmatrix}$.

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
e	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	-1.038	2.768	0.406	0.347	0.167	-1.894	0.380	3.137	0	0	0	0	0	0	1

(b) Submatrix $\begin{bmatrix} -\alpha_1 \\ U_2 \end{bmatrix}$ 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_2 , 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) B₂ CO Cl₂ F₂ H₂ F⁻ LiF N₂ O₂
- Al(liq) BF₃ CO₂ ClF HC1 Li⁺ LiH NO OH
- AlO BF₂
- Al₂O₃(g) BH
- Al₂O₃(s) BO
- Al₂O₃(liq) B₂O₃(g)
- B₂O₃(s)
- B₂O₃(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° at 298.16° K and every 100° from 300° to 6000° K. In many cases these C_p° data were smoothed by the following method: Values of the first differences of C_p° for 100° K intervals δC_p° were plotted against temperature and a smooth curve drawn. New values of C_p° were then computed from the values of δC_p° read from the curve. In some cases the new C_p° values were tabulated to more decimal places than the original data. Care was taken to see that the new C_p° 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° to obtain the other functions, a linear variation of C_p° was assumed by use of the equation

$$C_p^\circ = c_1 + c_2 T \quad (46)$$

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° 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° using the constants for each 100° K temperature interval.

The value of the change of enthalpy δH_T° for a temperature change $\delta T = T - T_1$ is given by

$$\delta H_T^\circ = \int_{T_1}^T C_p^\circ dT = \bar{C}_p^\circ \delta T \quad (47)$$

where \bar{C}_p° is given by

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

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

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

where $\delta \ln T$ is given by

$$\delta \ln T = \ln T - \ln T_1 \quad (50)$$

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° 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° 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 round-

ing 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° .—For convenience of computation, tables of enthalpy H_T° , the sum of the sensible enthalpy $H_T^\circ - H_0^\circ$ and chemical energy at 0° K H_0° , 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° 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° (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 ₂ O	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° to be assigned to a substance having a known heat of formation, it is convenient to use the values of H_T° assigned to the elements as shown in the following table:

Element	Phase	Enthalpy assigned, H_T° (kcal/mole)	
		0° K	298.16° K
A	Gas	0	1.4812
Al	Crystal	235.6261	234.0951
B	Crystal	-----	173.3793
C	Graphite	91.8274	92.1790
Cl ₂	Gas	7.8061	10.0000
F ₂	Gas	60.9562	63.0692
H ₂	Gas	67.4169	69.4407
Li	Crystal	-----	132.2250
N ₂	Gas	1.6922	3.7716
O ₂	Gas	2.0362	4.1109
e-	Gas	60.0000	61.4812

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



and ΔH_f° is defined as

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

therefore,

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

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

$$\begin{aligned} (H_{298.16}^\circ)_{H_2O(l)} &= -68,317.4 + 69,440.7 + \frac{1}{2}(4110.9) \\ &= 3178.75 \text{ (cal/mole)} \end{aligned}$$

For convenience, the values of H_T° 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° 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° and S_T° 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



From the definitions of ΔH° and $\ln K$

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

and

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

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

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

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° , linear interpolation yields self-consistent results for the C_p° 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° for any temperature T is given by

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

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° for H_2O at $1573.4^\circ K$ is computed to be

$$\begin{aligned} C_p^\circ &= 11.134 + \frac{73.4}{100} (11.343 - 11.134) \\ &= 11.287 \text{ (cal/(mole) } (^\circ K)) \end{aligned}$$

Interpolation of enthalpy.—The value of H_T° for any temperature T is given by

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

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

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

For example, for H_2O at $1573.4^\circ K$

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

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

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 be approximated by

$$\delta S_T^\circ = \bar{C}_p^\circ \delta \ln T \quad (60)$$

from which S_T° may be written

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

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

Equation (61) yields self-consistent values to within 0.0001 (cal/(mole) ($^\circ K$)) for all substances tabulated at temperatures above $1600^\circ K$ 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 $1600^\circ K$. For these substances, the error due to use of equation (61) does not exceed 0.0003 cal/(mole) ($^\circ K$), but equation (49) may be used if greater self-consistency is desired.

For example, for H_2O at $1573.4^\circ K$,

$$\begin{aligned} S_T^\circ &= 59.8687 + 11.211 (\ln 1573.4 - \ln 1500) \\ &= 60.4043 \text{ (cal/(mole) } (^\circ K)) \end{aligned}$$

By linear interpolation,

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

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

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

and

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

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 $1573.4^\circ K$,

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

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.

Al₂O₃(s, liq, g).—The properties of Al₂O₃ 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° given in reference 27. The value of $S_{298.16}^\circ$ 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° formula given in reference 27. The heat of fusion ($\Delta H_{\text{fusion}}^\circ = 6000$ cal/mole at 2320° K) was taken from reference 25. The C_p° values for Al₂O₃ (liq) above 2320° K were calculated from a formula based upon data given in reference 25.

Inasmuch as data on gaseous Al₂O₃ are unavailable in the literature, it was assumed that C_p° values for Al₂O₃(g) are the same as those for B₂O₃(g) given in reference 29. The heat of vaporization ($\Delta H_{\text{vaporization}}^\circ = 115.7$ kcal/mole at boiling point of $2980 \pm 60^\circ \text{C}$) 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.

BF₃.—The thermodynamic functions of BF₃ 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 (g)(cm ²)
	B ¹¹ F ₃ (cm ⁻¹)	B ¹⁰ F ₃ (cm ⁻¹)	
ν_1	888	888	$I_1 = 157.7 \times 10^{-40}$ $I_2 = 78.84 \times 10^{-40}$ $I_3 = 78.84 \times 10^{-40}$
ν_2	691.3	719.5	
$\nu_3(2)$	1445.9	1497	
$\nu_4(2)$	480.4	483.0	
Relative abundance (percent)	81.17	18.83	

B₂O₃ (g).—The value for the heat required to convert solid B₂O₃ at 0° K to gaseous B₂O₃ at 1500° K listed in reference 29 as 106.065 (kcal/mole) was used to compute the value of $(H_{1500}^\circ)_{\text{B}_2\text{O}_3(\text{g})}$. The values of $(S_{1500}^\circ)_{\text{B}_2\text{O}_3(\text{g})}$ and $(H_{1500}^\circ - H_0^\circ)_{\text{B}_2\text{O}_3(\text{g})}$ were taken from reference 29. The remaining values of enthalpy and entropy were computed by integration of the specific-heat data.

Cl₂ and HCl.—The C_p° data for Cl₂ 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° , H_T° , $-H_0^\circ$, and S_T° 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° 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° , $H_T^\circ - H_0^\circ$, and S_T° at 5000° K computed with these data differ from values herein by 1 percent for C_p° , 0.2 percent for $H_T^\circ - H_0^\circ$, and 0.03 percent for S_T° .

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° 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 $I_0 = 15.415 \times 10^{-40}$ (gm)(cm²) were graphically estimated from a plot of force constants against difference in atomic number of the two elements composing the substances NaH, C₂, 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 LiH¹ 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)(cm²).

H₂O(s), N₂(s), and O₂(s).—The heat required to heat solid H₂O, N₂, and O₂ 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 H₂, new values for C_p° , internal energy $E^\circ - E_0^\circ$, and S_T° were published in reference 45 and differ from the values in this report at 5000° K by 0.5 percent for C_p° , 0.1 percent for $H_T^\circ - H_0^\circ$, and 0.02 percent for S_T° .

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.

LEWIS FLIGHT PROPULSION LABORATORY,
 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, \dots	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°	molar specific heat at constant pressure and standard conditions (cal/(mole) (°K))
C', C''	specific heat coefficient for matrix
C_v°	molar specific heat at constant volume and standard conditions
D	operator $\left(\frac{\partial \log}{\partial \log T}\right)_s$
E_T°	molar internal energy at standard conditions
e	internal energy per equivalent formula
F_T°	molar free energy at standard conditions
g	gas phase of substance
H_0°	chemical energy at 0° K and standard conditions (kcal/mole)
H_T°	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
ΔH_f°	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) (cm ²)
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°	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, \dots	elements within representative chemical formula
x	correction variables
$\alpha_1, \alpha_2, \dots$	submatrices
Δ	increment
δ	increment due to a temperature change; with subscript, error parameter
ϵ	total-error parameter
$\nu_1, \nu_2, \nu_3(2)$ $\nu_4(2)$	spectroscopic constants
$\omega_s, \omega_e 2^s$	spectroscopic constants
ρ	density
Subscripts:	
a, b, \dots	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)
$\dots Y, Z$	product index numbers (i) that designate atomic gases
$1, 2, \dots,$ $i, \dots N$	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	$(H_i^0)_i$ kcal/mole	$(\Delta H_i^0/RT)_i$	$(S_i^0)_i$	$(C_p)_i$	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 ₂ O ₃	2	2	0	0	3	283.435	-80.5332	116.760	26.660	5.1094
BF	3	1	0	1	0	262.961	-17.2834	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	262.739	-18.1834	69.620	9.065	1.0327
B ₂	6	2	0	0	0	572.053	-7.9592	70.580	8.923	-2.7625
H ₂	7	0	2	0	0	99.593	-13.9835	51.054	9.151	-0.4061
H ₂ O	8	0	2	0	1	57.706	-20.2092	72.458	13.300	-0.3470
OH	9	0	1	0	1	78.560	-13.6031	63.989	9.185	-0.1663
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	106.192	-----	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_i⁰ ASSIGNED TO SEVERAL SUBSTANCES

Substance	Formula	Phase	Temperature (°K)	Heat of formation, ΔH _f ⁰ (kcal/mole)	Enthalpy assigned, H _i ⁰ (kcal/mole)	Reference
Acetylene	C ₂ H ₂	Gas	298.16	54.194	307.983	11
		Liquid*	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	-----	-88.91	10, 14
Aniline	C ₆ H ₅ NH ₂	Liquid	298.16	48.18	806.19	14
n-Butane	C ₄ H ₁₀	Gas	298.16	-29.812	658.108	12
		Liquid	272.66	-----	*650.126	12, 14
Chlorine	Cl ₂	Gas	298.16	0	10.000	-----
		Liquid	239.11	-----	*4.61	15
Chlorine trifluoride	ClF ₃	Liquid	298.16	-32.1	67.5	-----
Diborane	B ₂ H ₆	Gas	298.16	7.5	662.6	16
		Liquid	180.63	-----	557.8	16, 17
Ethylene diamine	C ₂ H ₄ N ₂	Liquid	298.16	-6.36	459.53	11
Fluorine	F ₂	Gas	298.16	0	63.0699	-----
		Liquid	85.24	-----	60.04	18
Fluorine oxide	F ₂ O	Gas	298.16	5.5	70.6	18
		Liquid	128.3	-----	68.4	18
Gasoline ^f	AN-F-68	Liquid	298.16	-47.50	1348.60	-----
Heptane	C ₇ H ₁₆	Liquid	298.16	-53.63	1147.15	12
Hexane	C ₆ H ₁₄	Liquid	298.16	-47.62	991.64	12
Hydrazine	N ₂ H ₄	Liquid	298.16	12.05	154.70	10
Hydrazine hydrate	N ₂ H ₄ ·H ₂ O	Liquid	298.16	-57.93	156.20	10
Hydrogen	H ₂	Gas	298.16	0	69.4407	-----
		Liquid	20.89	-----	*67.546	19
Hydrogen peroxide	H ₂ O ₂	Liquid	298.16	-44.84	28.71	18
Hydroxylamine	NH ₂ OH	Liquid	298.16	-26.5	82.6	10
Lithium	Li	Crystal	298.16	0	132.2250	-----
		Liquid	459.16	-----	134.63	20, 21
Lithium borohydride	LiBH ₄	Crystal	298.16	-44.15	400.34	22
Methane	CH ₄	Gas	298.16	-17.839	213.171	12
		Liquid	111.67	-----	209.71	12
Methanol	CH ₃ OH	Liquid	298.16	-57.036	178.080	23
Nitric acid, white fuming	HNO ₃	Liquid	298.16	-41.404	1.368	10
Nitrogen tetroxide	N ₂ O ₄	Gas	298.16	2.309	14.302	10
		Liquid	294.31	-----	5.120	10
Nitrogen trifluoride	NF ₃	Gas	298.16	-27.2	69.3	10
		Liquid	144.1	-----	64.6	10
Nitromethane	CH ₃ NO ₂	Liquid	298.16	-29.7	175.6	23
n-Octane	C ₈ H ₁₈	Liquid	298.16	-53.74	1302.66	12
Oxygen	O ₂	Gas	298.16	0	4.1109	-----
		Liquid	90.18	-----	1.0314	8, 18
Ozone	O ₃	Gas	298.16	34.0	40.2	18
		Liquid	162.65	-----	36.4	18
Pentaborane	B ₅ H ₉	Liquid	298.16	7.8	1187.2	16
Tetranitromethane	C(N ₂ O ₂) ₄	Liquid	298.16	5	121	23
Water	H ₂ O	Gas	298.16	-57.7979	13.6988	18
		Liquid	298.16	-----	*3.1788	18

* For pressure of 900 mm Hg.
^b For composition consisting of following mole fractions: N₂, 0.780831; O₂, 0.209465; A, 0.009324; CO₂, 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 Company.
^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, ΔH_f° (kcal/mole)		Spectroscopic constants		Reference			
		0° K	298.16° K	$\omega_e - 2\omega_e x_e^2$ (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						
Al	Gas		67.50			(b)	24	(a)	(a)
Al	Crystal	0	0				24	(a)	(a)
Al	Liquid							25	a d 25
AlF ₃	Crystal		-329.3			(b)			
AlO	Gas		37.8	963	43.8223	(b)	26	(c)	(c)
Al ₂ O ₃	Gas								(f)
Al ₂ O ₃	Crystal, α		-399.09			(b)		27	27
Al ₂ O ₃	Liquid							25	25
B	Gas		97.2				26	29	(a)
B	Crystal	0	0						(a)
B ₂	Gas		124				26	29	a d 26
BF ₃	Gas		-16.9308	1304.84	19.9465	b 30	f 30	(c)	(c)
BF ₃	Gas		-265.2			28	f 31	(c)	(c)
BH ₃	Gas		73.8	2268	2.36939	28	26	(c)	(c)
BO	Gas		-5.2			28		29	a d 29
B ₂ O ₃	Gas					(f)			a d 29
B ₂ O ₃	Crystal		-302.0			28		29	29
B ₂ O ₃	Liquid							29	a d 29
C	Gas		171.898			23		11	a d 11
C	Graphite	0	0						
CO	Gas		-26.4157			23		32	a d 11
CO ₂	Gas		-94.0518			23		32	a d 11
Cl	Gas	28.61				33		11	a d 11
Cl ₂	Gas	0						11	(f)
ClF	Gas		-13.2	778	64.35	(f)	34	(c)	(c)
F	Gas	17.8				(f)	35	(c)	(c)
F ₂	Gas	0	0	856	33.3564		36	(c)	(c)
H	Gas	51.620				18		32	32
H ₂	Gas	0	0					32	a d 19
HCl	Gas		-22.063			11		11	(f)
HF	Gas		-64.2			18	36	(f)	(f)
H ₂ O	Gas		-57.7974			18		11	a d 11
H ₂ O	Crystal		-68.4350			b 37			
H ₂ O	Liquid		-68.3174			18			
H ₂ O	Gas	0	0					38	38
H ₂ O	Gas	-78.5				h 18	(f)		
LiF	Gas		161.4664			h 24	24	(c)	(a)
Li	Gas		36.150			l 20	24	(a)	(a)
Li	Crystal	0	0						
LiF	Gas		-33.786	1343	15.415	l 20	(f)	(c)	(c)
LiH	Gas		25.4564	1360.37	2.77246	h 39	f 26	(c)	(c)
N	Gas	85.120				10		32	a d 11
N ₂	Gas	0	0					32	a d 11
N ₂	Crystal	-1.6992				h 37			
NO	Gas	21.477				10		18	a d 11
O	Gas	58.585				32		32	a d 11
O ₂	Gas	0	0					8	a d 8
O ₂	Crystal	-2.0362				h 37			
OH	Gas	10.0				18		32	a d 11

* 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 ^o ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)	H _T ^o -H ₀ ^o (kcal/mole)	H _T ^o (kcal/mole)	S _T ^o ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)
0		0	0	
298.16	4.9680	1.4812	1.4812	38.9630
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	41.8582
900	4.9680	4.4712	4.4712	42.3714
1,000	4.9680	4.9680	4.9680	42.8648
1,100	4.9680	5.4648	5.4648	43.3483
1,200	4.9680	5.9616	5.9616	43.8006
1,300	4.9680	6.4584	6.4584	44.2322
1,400	4.9680	6.9552	6.9552	44.6434
1,500	4.9680	7.4520	7.4520	45.0341
1,600	4.9680	7.9488	7.9488	45.4046
1,700	4.9680	8.4456	8.4456	45.7549
1,800	4.9680	8.9424	8.9424	46.0949
1,900	4.9680	9.4392	9.4392	46.4246
2,000	4.9680	9.9360	9.9360	46.7438
2,100	4.9680	10.4328	10.4328	47.0527
2,200	4.9680	10.9296	10.9296	47.3511
2,300	4.9680	11.4264	11.4264	47.6397
2,400	4.9680	11.9232	11.9232	47.9181
2,500	4.9680	12.4200	12.4200	48.1869
2,600	4.9680	12.9168	12.9168	48.4458
2,700	4.9680	13.4136	13.4136	48.6943
2,800	4.9680	13.9104	13.9104	48.9329
2,900	4.9680	14.4072	14.4072	49.1611
3,000	4.9680	14.9040	14.9040	49.3794
3,100	4.9680	15.4008	15.4008	49.5883
3,200	4.9680	15.8976	15.8976	49.7873
3,300	4.9680	16.3944	16.3944	49.9769
3,400	4.9680	16.8912	16.8912	50.1566
3,500	4.9680	17.3880	17.3880	50.3268
3,600	4.9680	17.8848	17.8848	50.4871
3,700	4.9680	18.3816	18.3816	50.6379
3,800	4.9680	18.8784	18.8784	50.7796
3,900	4.9680	19.3752	19.3752	50.9126
4,000	4.9680	19.8720	19.8720	51.0373
4,100	4.9680	20.3688	20.3688	51.1531
4,200	4.9680	20.8656	20.8656	51.2604
4,300	4.9680	21.3624	21.3624	51.3596
4,400	4.9680	21.8592	21.8592	51.4511
4,500	4.9680	22.3560	22.3560	51.5353
4,600	4.9680	22.8528	22.8528	51.6117
4,700	4.9680	23.3496	23.3496	51.6806
4,800	4.9680	23.8464	23.8464	51.7424
4,900	4.9680	24.3432	24.3432	51.7976
5,000	4.9680	24.8400	24.8400	51.8466
5,100	4.9680	25.3368	25.3368	51.8898
5,200	4.9680	25.8336	25.8336	51.9276
5,300	4.9680	26.3304	26.3304	51.9604
5,400	4.9680	26.8272	26.8272	51.9886
5,500	4.9680	27.3240	27.3240	52.0126
5,600	4.9680	27.8208	27.8208	52.0328
5,700	4.9680	28.3176	28.3176	52.0496
5,800	4.9680	28.8144	28.8144	52.0626
5,900	4.9680	29.3112	29.3112	52.0724
6,000	4.9680	29.8080	29.8080	52.0796

TABLE V—THERMODYNAMIC PROPERTIES OF Al (GAS)

[Atomic weight, 26.97]

T (°K)	C _p ^o ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)	H _T ^o -H ₀ ^o (kcal/mole)	H _T ^o (kcal/mole)	S _T ^o ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)
0		0	0	
298.16	5.1122	1.6535	300.5416	30.3027
300	5.1104	1.6629	302.2045	30.3342
400	5.0469	2.1703	302.7119	30.7943
500	5.0178	2.6734	303.2150	31.1970
600	5.0022	3.1743	303.7169	31.5304
700	4.9929	3.6740	304.2156	31.8007
800	4.9880	4.1730	304.7146	32.0270
900	4.9829	4.6715	305.2131	32.2191
1000	4.9800	5.1696	305.7112	32.3790
1100	4.9778	5.6675	306.2091	32.5135
1200	4.9762	6.1652	306.7068	32.6244
1300	4.9750	6.6628	307.2044	32.7122
1400	4.9740	7.1602	307.7018	32.7873
1500	4.9732	7.6576	308.1992	32.8506
1600	4.9726	8.1549	308.6965	32.9027
1700	4.9720	8.6521	309.1937	32.9438
1800	4.9716	9.1493	309.6909	32.9743
1900	4.9712	9.6464	310.1880	32.9954
2000	4.9709	10.1435	310.6851	33.0076
2100	4.9706	10.6406	311.1822	33.0116
2200	4.9704	11.1376	311.6792	33.0073
2300	4.9702	11.6347	312.1763	33.0046
2400	4.9700	12.1317	312.6733	33.0031
2500	4.9699	12.6287	313.1703	33.0031
2600	4.9698	13.1257	313.6673	33.0043
2700	4.9698	13.6226	314.1642	33.0063
2800	4.9698	14.1196	314.6612	33.0092
2900	4.9699	14.6166	315.1582	33.0136
3000	4.9701	15.1136	315.6552	33.0191
3100	4.9704	15.6106	316.1522	33.0254
3200	4.9709	16.1077	316.6493	33.0322
3300	4.9716	16.6048	317.1464	33.0391
3400	4.9724	17.1020	317.6435	33.0463
3500	4.9735	17.5993	318.1406	33.0536
3600	4.9750	18.0968	318.6384	33.0616
3700	4.9768	18.5943	319.1369	33.0701
3800	4.9791	19.0921	319.6367	33.0791
3900	4.9818	19.5902	320.1381	33.0886
4000	4.9851	20.0885	320.6401	33.0986
4100	4.9890	20.5872	321.1428	33.1091
4200	4.9936	21.0864	321.6460	33.1201
4300	4.9990	21.5860	322.1496	33.1316
4400	5.0052	22.0862	322.6536	33.1436
4500	5.0122	22.5871	323.1581	33.1561
4600	5.0203	23.0887	323.6633	33.1691
4700	5.0294	23.5912	324.1691	33.1826
4800	5.0396	24.0946	324.6754	33.1966
4900	5.0510	24.5992	325.1821	33.2111
5000	5.0637	25.1049	325.6893	33.2261
5100	5.0776	25.6120	326.1969	33.2416
5200	5.0928	26.1205	326.7049	33.2576
5300	5.1094	26.6306	327.2132	33.2741
5400	5.1275	27.1424	327.7219	33.2911
5500	5.1470	27.6562	328.2309	33.3086
5600	5.1680	28.1719	328.7401	33.3266
5700	5.1905	28.6893	329.2496	33.3451
5800	5.2145	29.2083	329.7593	33.3641
5900	5.2401	29.7288	330.2693	33.3836
6000	5.2672	30.2502	330.7796	33.4036

TABLE VI.—THERMODYNAMIC PROPERTIES OF Al
 (CRYSTAL)

[Atomic weight, 26.97]

T (°K)	C_p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$H_f - H_g$ (kcal/mole)	H_f (kcal/mole)	S_f ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^\circ}{RT}$	$\log K$
0	-----	0	233.6261	-----	-----	-----
298.16	5.80	1.0700	234.6961	6.641	113.9245	42.3389
300	5.81	1.0820	234.7071	6.682	113.2214	42.0354
400	6.24	1.6860	235.3111	8.319	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	56.2896	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	11.4090
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 ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$H_f - H_g$ (kcal/mole)	H_f (kcal/mole)	S_f ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^\circ}{RT}$	$\delta \left(-\frac{\Delta H^\circ}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$		$\log K$	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
930	6.75	7.8240	241.4491	16.818	34.5338	-----	-----	8.8566	-----	-----
1000	6.84	8.2890	241.9241	17.310	32.0963	3271	0.03246	7.8061	1414	-0.01965
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	5.4983	1178	-0.01955
1300	7.218	10.4077	244.0328	19.1520	24.4536	2517	.03174	4.6027	1087	-0.01923
1400	7.344	11.1388	244.7609	19.6915	22.6239	2337	.03190	3.8455	1009	-0.01887
1500	7.470	11.8765	245.5016	20.2025	21.0340	2181	.03198	3.1917	941	-0.01832
1600	7.596	12.6298	246.2549	20.6886	19.6389	2045	0.03188	2.6219	882	-0.01812
1700	7.722	13.3957	247.0208	21.1529	18.4041	1925	.03165	2.1212	830	-0.01811
1800	7.848	14.1742	247.7993	21.5978	17.3030	1818	.03166	1.6782	784	-0.01803
1900	7.974	14.9653	248.5904	22.0255	16.3145	1722	.03190	1.2836	742	-0.01780
2000	8.100	15.7690	249.3941	22.4377	15.4210	1636	.03175	.9302	705	-0.01751
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	-0.01706
2300	8.478	18.1857	251.8808	23.5966	13.1923	1423	.03168	.0632	612	-0.01700
2400	8.604	19.1008	252.7349	23.9591	12.5677	1363	.03190	-.1748	586	-0.01670
2500	8.730	19.9765	253.6016	24.3129	11.9906	1309	.03174	-.3925	562	-0.01655
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	-0.01631
2800	9.108	22.6522	256.2773	25.3233	10.4930	1169	.03170	-.9452	501	-0.01616
2900	9.234	23.5693	257.1944	25.6451	10.0582	1129	.03147	-1.1018	483	-0.01600
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 (cal/mole °K)	H _T ^o -H ₀ ^o (kcal/mole)	H _T ^o (kcal/mole)	S _T ^o (cal/mole °K)	ΔH ^o RT	δ(-ΔH ^o /RT) - δT(a/T+b)		log K	δ log K = -δT(c/T+d)	
						a	b		c	d
0	-----	0	272.4501	-----	-----	-----	-----	-----	-----	-----
288.16	7.3749	2.1005	274.5806	52.1645	149.9686	-----	-----	59.5342	-----	-----
300	7.3820	2.1140	274.6641	52.2101	148.0580	-----	-----	59.1348	-----	-----
400	7.7510	2.8711	278.8212	54.8856	112.1309	-----	-----	42.9281	-----	-----
500	8.0424	3.6616	278.1116	56.1482	89.9293	-----	-----	33.1770	-----	-----
600	8.2530	4.4769	276.9270	57.6342	75.1020	-----	-----	26.6809	-----	-----
700	8.4035	5.3101	277.7802	58.8153	64.4956	-----	-----	21.9971	-----	-----
800	8.5122	6.1662	278.6063	60.0479	56.5311	-----	-----	18.4930	-----	-----
900	8.5924	7.0116	279.4617	61.0533	50.3305	-----	-----	15.7829	-----	-----
1000	8.6529	7.8740	280.3241	61.9639	45.3858	4456	0.01879	13.6755	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	282.0636	63.5493	37.9118	3719	0.00683	10.2874	1632	0.01202
1300	8.7645	10.4884	282.9385	64.2496	35.0425	3435	0.00493	9.0200	1506	0.01056
1400	8.7878	11.3660	283.8161	64.9000	32.5820	3191	0.00397	7.9323	1402	0.00923
1500	8.8069	12.2457	284.6966	65.5070	30.4487	2980	0.00300	6.9884	1309	0.00858
1600	8.8227	13.1272	285.5773	66.0769	28.5815	2795	0.00388	6.1614	1228	0.00825
1700	8.8359	14.0101	286.4602	66.6111	26.9335	2632	0.00306	5.4308	1157	0.00752
1800	8.8471	14.8943	287.3444	67.1165	25.4882	2487	0.00245	4.7806	1094	0.00671
1900	8.8566	15.7795	288.2296	67.5951	24.1688	2357	0.00190	4.1980	1037	0.00630
2000	8.8647	16.6655	289.1166	68.0496	22.9784	2240	0.00153	3.6782	986	0.00568
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	0.00115	2.7650	898	0.00517
2300	8.8833	19.3279	291.7780	69.2899	20.0500	1949	0.00102	2.3894	859	0.00508
2400	8.8880	20.2163	292.6666	69.6680	19.2369	1869	0.00090	2.0664	824	0.00480
2500	8.8922	21.1055	293.5556	70.0309	18.4858	1795	0.00022	1.6720	791	0.00477
2600	8.8960	21.9949	294.4450	70.3798	17.7982	1727	-0.00013	1.3630	761	0.00455
2700	8.8993	22.8847	295.3348	70.7156	17.1687	1663	-0.00023	1.0766	734	0.00416
2800	8.9022	23.7747	296.2248	71.0393	16.5950	1605	-0.00065	0.8103	708	0.00406
2900	8.9050	24.6651	297.1162	71.3517	16.0722	1550	-0.00087	0.5921	684	0.00390
3000	8.9074	25.5557	298.0088	71.6538	15.4964	1500	-0.00127	0.3802	662	0.00375
3100	8.9096	26.4466	298.8997	71.9458	15.0138	1452	-0.00145	0.1129	640	0.00380
3200	8.9116	27.3376	299.7877	72.2287	14.5615	1407	-0.00156	-0.0900	621	0.00362
3300	8.9134	28.2289	300.6790	72.5029	14.1367	1365	-0.00177	-0.2827	602	0.00364
3400	8.9150	29.1202	301.5704	72.7690	13.7370	1325	-0.00216	-0.4634	584	0.00354
3500	8.9166	30.0119	302.4620	73.0275	13.3608	1289	-0.00236	-0.6389	568	0.00342
3600	8.9180	30.9038	303.3537	73.2787	13.0046	1254	-0.00252	-0.7952	562	0.00351
3700	8.9193	31.7956	304.2456	73.5230	12.6682	1221	-0.00282	-0.9479	538	0.00332
3800	8.9205	32.6875	305.1376	73.7609	12.3497	1190	-0.00313	-1.0928	524	0.00324
3900	8.9216	33.5796	306.0297	73.9927	12.0477	1160	-0.00320	-1.2304	511	0.00315
4000	8.9226	34.4718	306.9219	74.2186	11.7609	1132	-0.00350	-1.3613	498	0.00314
4100	8.9235	35.3641	307.8142	74.4389	11.4883	1106	-0.00383	-1.4859	486	0.00319
4200	8.9244	36.2565	308.7066	74.6539	11.2289	1081	-0.00420	-1.6048	475	0.00303
4300	8.9252	37.1490	309.5991	74.8639	10.9817	1057	-0.00443	-1.7183	464	0.00295
4400	8.9260	38.0415	310.4916	75.0691	10.7459	1034	-0.00468	-1.8267	454	0.00291
4500	8.9267	38.9342	311.3843	75.2697	10.5208	1012	-0.00490	-1.9305	444	0.00288
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	-0.00580	-2.1252	425	0.00286
4800	8.9286	41.6125	314.0625	75.8459	9.9031	953	-0.00579	-2.2166	416	0.00300
4900	8.9291	42.5054	314.9555	76.0300	9.7144	935	-0.00610	-2.3045	407	0.00300
5000	8.9296	43.3983	315.8484	76.2104	9.5335	918	-0.00650	-2.3889	400	0.00267
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	-0.00707	-2.5484	384	0.00295
5300	8.9310	46.0774	318.5275	76.7308	9.0338	871	-0.00740	-2.6238	377	0.00289
5400	8.9314	46.9705	319.4206	76.8977	8.8794	857	-0.00782	-2.6965	369	0.00301
5500	8.9318	47.8637	320.3138	77.0616	8.7314	843	-0.00814	-2.7666	363	0.00298
5600	8.9322	48.7569	321.2070	77.2228	8.5890	830	-0.00851	-2.8344	356	0.00304
5700	8.9326	49.6501	322.1002	77.3807	8.4519	817	-0.00876	-2.8999	349	0.00313
5800	8.9329	50.5434	322.9935	77.5360	8.3193	805	-0.00904	-2.9632	343	0.00316
5900	8.9332	51.4367	323.8868	77.6887	8.1924	793	-0.00947	-3.0245	337	0.00323
6000	8.9335	52.3300	324.7801	77.8389	8.0697	-----	-----	-3.0839	-----	-----

REPORT 1037—NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TABLE IX—THERMODYNAMIC PROPERTIES OF Al₂O₃ (CRYSTAL, α)

[Molecular weight, 101.94]

T (°K)	C _p ^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H _T ^o - H ₁₀₀₀ ^o (kcal/mole)	H _T ^o (kcal/mole)	S _T ^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^o}{RT}$	$\delta - \left(\frac{\Delta H^o}{RT}\right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b\right)$		log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d\right)$	
						a	b		c	d
0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
298.16	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
300	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
400	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
500	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
600	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
700	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
800	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
900	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1000	23.380	0	237.0838	91.5490	288.1479	28.430	0.10445	95.1916	12.409	0.01799
1100	23.754	2.3557	239.4395	93.7939	280.1980	25.870	0.08207	83.8927	11.287	0.01187
1200	24.064	4.7466	241.8304	95.8741	283.5576	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	246.6602	99.6189	204.6218	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	24.805	14.5394	251.6232	102.9120	178.9710	17.848	0.02935	48.5668	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	107.2903	150.7062	15.048	.01760	36.2668	6.547	-.00100
2000	25.159	24.5392	261.6230	108.6890	143.1646	14.300	.01538	33.0243	6.220	-.00130
2100	25.221	27.0682	264.1420	109.7180	136.5397	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	22.6830	5.185	-.00210
2500	25.408	37.1876	274.2714	114.1327	114.4897	11.460	.00601	20.5911	4.977	-.00193

TABLE XII—THERMODYNAMIC PROPERTIES OF B (GAS)

[Atomic weight, 10.82]

T (°K)	C_p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$H_T - H_0$ ($\frac{\text{kcal}}{\text{mole}}$)	H_T ($\frac{\text{kcal}}{\text{mole}}$)	S_T ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)
0	-----	0	269.0696	-----
298.16	4.9704	1.5097	270.5793	38.0493
300	4.9704	1.5158	270.5884	38.0798
400	4.9883	2.0168	271.0854	38.1096
500	4.9888	2.5127	271.5823	38.2183
600	4.9886	3.0036	272.0792	40.1243
700	4.9884	3.5084	272.5760	40.8902
800	4.9883	4.0089	273.0729	41.5536
900	4.9882	4.5001	273.5697	42.1388
1000	4.9882	4.9899	274.0666	42.6625
1100	4.9882	5.4937	274.5633	43.1370
1200	4.9881	5.9906	275.0601	43.5688
1300	4.9881	6.4874	275.5570	43.9669
1400	4.9881	6.9842	276.0538	44.3341
1500	4.9881	7.4810	276.5506	44.6769
1600	4.9881	7.9778	277.0474	44.9975
1700	4.9881	8.4746	277.5442	45.2987
1800	4.9880	8.9714	278.0410	45.5827
1900	4.9880	9.4682	278.5378	45.8513
2000	4.9880	9.9650	279.0346	46.1061
2100	4.9880	10.4618	279.5314	46.3485
2200	4.9880	10.9586	280.0282	46.5796
2300	4.9880	11.4554	280.5250	46.8004
2400	4.9880	11.9522	281.0218	47.0119
2500	4.9880	12.4490	281.5186	47.2147
2600	4.9880	12.9458	282.0154	47.4095
2700	4.9880	13.4426	282.5122	47.5970
2800	4.9880	13.9394	283.0090	47.7777
2900	4.9880	14.4362	283.5058	47.9520
3000	4.9880	14.9330	284.0026	48.1204
3100	4.9880	15.4298	284.4994	48.2833
3200	4.9880	15.9266	284.9962	48.4410
3300	4.9880	16.4234	285.4930	48.5939
3400	4.9880	16.9202	285.9898	48.7422
3500	4.9880	17.4170	286.4866	48.8862
3600	4.9880	17.9138	286.9834	49.0262
3700	4.9880	18.4106	287.4802	49.1623
3800	4.9880	18.9074	287.9770	49.2948
3900	4.9880	19.4042	288.4738	49.4238
4000	4.9881	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	22.3851	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 B₂ (GAS)

[Molecular weight, 21.64]

T (°K)	C _p (cal/mole °K)	H _f °-H _g (kcal/mole)	H _f (kcal/mole)	S _f (cal/mole °K)	ΔH° RT	a(-ΔH°/RT) = -δT(a/T + b)		log K	δ log K = -δT(c/T + d)	
						α	b		c	d
0		0	468.8652							
298.16	7.289	2.0834	470.7586	48.682	118.8190			48.2180		
300	7.295	2.1066	470.7720	48.697	118.0863			48.8925		
400	7.645	2.8540	471.6192	50.844	88.8442			33.0502		
500	7.990	3.6938	472.2680	52.684	71.3228			25.3251		
600	8.165	4.4398	473.1050	54.082	59.6932			20.1558		
700	8.330	5.2646	473.9298	55.323	51.2012			16.4542		
800	8.460	6.1042	474.7694	56.444	44.8980			13.6715		
900	8.540	6.9537	475.6189	57.445	39.9899			11.5932		
1000	8.608	7.8116	476.4767	58.348	36.0693	8326	0.01326	9.7646	1562	0.01399
1100	8.665	8.6751	477.3403	59.1711	32.8406	2209	0.01003	8.8397	1413	0.01210
1200	8.704	9.5436	478.2088	59.9267	30.1594	2044	.00798	7.1501	1296	.01138
1300	8.738	10.4157	479.0809	60.6248	27.8838	2720	.00624	6.1416	1198	.00999
1400	8.764	11.2898	479.9560	61.2732	26.0347	2528	.00487	5.2761	1113	.00940
1500	8.784	12.1682	480.8334	61.8786	24.2447	2359	.00362	4.5247	1040	.00860
1600	8.808	13.0475	481.7127	62.4461	22.7663	2213	0.00404	3.8661	978	0.00783
1700	8.820	13.9287	482.6939	62.9803	21.4696	2084	.00342	3.2841	919	.00764
1800	8.832	14.8113	483.6765	63.4848	20.2983	1969	.00283	2.7859	869	.00698
1900	8.842	15.6950	484.6602	63.9626	19.2591	1866	.00230	2.3016	824	.00650
2000	8.852	16.5797	485.6449	64.4164	18.3235	1774	.00184	1.8831	784	.00597
2100	8.860	17.4653	486.6305	64.8484	17.4790	1690	0.00172	1.5038	747	0.00585
2200	8.868	18.3517	487.6169	65.2608	16.7070	1614	.00136	1.1886	714	.00527
2300	8.874	19.2388	487.6040	65.6551	16.0039	1544	.00127	.8429	683	.00522
2400	8.880	20.1265	488.5917	66.0329	15.3633	1480	.00120	.5531	655	.00300
2500	8.884	21.0147	489.5799	66.3955	14.7661	1421	.00106	.2861	630	.00449
2600	8.888	21.9033	490.5685	66.7440	14.2185	1367	0.00080	0.0393	606	0.00446
2700	8.891	22.7922	491.5574	67.0795	13.7114	1316	.00090	-.1696	584	.00423
2800	8.895	23.6815	492.5467	67.4029	13.2405	1270	.00067	-.4024	564	.00392
2900	8.898	24.5712	493.5364	67.7151	12.8019	1228	.00063	-.6068	546	.00383
3000	8.901	25.4611	494.5263	68.0168	12.3926	1185	.00074	-.7863	527	.00370
3100	8.903	26.3513	495.5165	68.3067	12.0096	1147	0.00066	-.9660	511	0.00341
3200	8.906	27.2418	496.5070	68.5914	11.6505	1111	.00063	-.1.2321	495	.00340
3300	8.908	28.1325	497.4977	68.8656	11.3132	1078	.00064	-.1.2765	481	.00323
3400	8.910	29.0234	497.8886	69.1314	10.9956	1046	.00064	-.1.4212	466	.00336
3500	8.912	29.9145	498.5797	69.3898	10.6952	1016	.00068	-.1.5777	453	.00327
3600	8.915	30.8058	499.4710	69.6409	10.4134	988	0.00037	-.1.6868	441	0.00311
3700	8.917	31.6974	500.3626	69.8852	10.1498	961	.00061	-.1.8001	429	.00311
3800	8.919	32.5892	501.2544	70.1230	9.8928	936	.00030	-.1.9251	419	.00286
3900	8.921	33.4812	502.1464	70.3547	9.6518	912	.00080	-.2.0354	408	.00280
4000	8.923	34.3734	503.0386	70.5806	9.4232	889	.36037	-.2.1402	398	.00283
4100	8.925	35.2658	503.9310	70.8009	9.2068	867	0.00067	-.2.2401	389	0.00268
4200	8.927	36.1584	504.8236	71.0160	8.9987	847	.00052	-.2.3354	380	.00263
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	806	.06054	-.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	758	.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	44.1941	512.8693	72.7516	7.4993	695	0.00105	-.3.0289	315	0.00212
5200	8.959	45.0883	513.7650	72.9255	7.3646	682	.00102	-.3.0916	309	.00210
5300	8.963	45.9839	514.6611	73.0962	7.2349	669	.00101	-.3.1520	303	.00209
5400	8.968	46.8825	515.5577	73.2638	7.1100	658	.00118	-.3.2102	298	.00202
5500	8.973	47.7895	516.4547	73.4284	6.9893	644	.00110	-.3.2664	293	.00188
5600	8.979	48.6871	517.3523	73.5901	6.8735	632	0.00122	-.3.3206	286	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	520.0486	74.0592	6.5485	599	.00137	-.3.4727	273	.00190
6000	9.005	52.2837	520.9489	74.2105	6.4478			-.3.5201		

TABLE XIV—THERMODYNAMIC PROPERTIES OF BF (GAS)

[Molecular weight, 29.82]

T (°K)	C _p (cal/mole °K)	H _f ^o -H _o ^o (kcal/mole)	H _f ^o (kcal/mole)	S _f ^o (cal/mole °K)	ΔH ^o RT	δ (-ΔH ^o / RT) - δT (a / T + b)		log K	δ log K = -δT / 100 (c / T + d)	
						a	b		c	d
0		0	218.1759							
208.16	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			49.8690		
500	7.5718	3.5539	221.7298	51.6695	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	5.9294	224.1013	55.3710	63.8146			21.3064		
900	8.3024	6.7495	224.9255	56.3416	56.8273			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	8.5494	9.2909	227.4568	58.7673	42.8224	4189	.01589	12.0406	1844	.01304
1300	8.5986	10.1582	228.3142	59.4533	39.5842	3870	.01241	10.6091	1704	.01106
1400	8.6415	11.0003	229.1762	60.0924	36.8065	3597	.01100	9.3933	1584	.01040
1500	8.6770	11.8663	230.0422	60.6898	34.3975	3360	.00900	8.3139	1480	.00920
1600	8.7063	12.7555	230.9115	61.2503	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	.00558	5.8198	1230	.00747
1900	8.7717	15.3680	233.5340	62.7529	27.2886	2659	.00500	5.1618	1172	.00690
2000	8.7875	16.2660	234.4120	63.2032	26.9541	2528	.00459	4.5689	1116	.00616
2100	8.8013	17.1155	235.2914	63.6323	24.7463	2408	0.00376	4.0318	1062	0.00597
2200	8.8133	17.9662	236.1722	64.0420	22.6420	2300	.00310	3.5421	1015	.00550
2300	8.8239	18.8781	237.0540	64.4340	20.6449	2201	.00232	3.0963	971	.00542
2400	8.8332	19.7610	237.9369	64.8093	21.7250	2110	.00240	2.6833	931	.00520
2500	8.8415	20.6447	238.8206	65.1705	20.8788	2026	.00227	2.3087	894	.00505
2600	8.8489	21.5292	239.7052	65.5175	20.0971	1949	0.00195	1.9598	860	0.00498
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	.00182	1.3367	801	.00399
2900	8.8668	24.1867	242.3628	66.4848	18.0761	1749	.00130	1.0555	774	.00380
3000	8.8716	25.0736	243.2496	66.7855	17.4908	1691	.00122	.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	26.8498	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	0.00261
4200	8.9059	35.7435	253.9195	69.7769	12.6462	1210	.00050	-1.3884	538	.00265
4300	8.9075	36.6342	254.8101	69.9865	12.3683	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	-1.8669	492	0.00252
4700	8.9132	40.1983	258.3743	70.7790	11.3563	1082	.00038	-1.9741	482	.00238
4800	8.9144	41.0897	259.2657	70.9667	11.1329	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	72.6548	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 ($\frac{cal}{mole \cdot ^\circ K}$)	$H_f - H_f^0$ ($\frac{kcal}{mole}$)	H_f ($\frac{kcal}{mole}$)	S_f ($\frac{cal}{mole \cdot ^\circ K}$)	$-\frac{\Delta H^0}{RT}$	$s \left(\frac{\Delta H^0}{RT} \right) = \frac{-sT}{100} \left(\frac{a}{T} + b \right)$		log K	$s \log K = \frac{-sT}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0		0	0							
298.18	12.0621	2.7842	2.7842	60.6958	704.3124			288.2741		
300	12.0681	2.8068	2.8068	60.7712	700.0296			284.3981		
400	13.7943	4.1030	4.1030	64.4394	526.0482			206.3238		
500	15.0594	5.5471	5.5471	67.7061	421.4916			162.5978		
600	16.0460	7.1046	7.1046	70.5483	351.6741			132.0708		
700	16.7919	8.7482	8.7482	73.0755	301.7803			110.2416		
800	17.3580	10.4570	10.4570	75.3664	264.2236			92.8552		
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	0.02185
1100	18.3922	15.8380	15.8380	81.0598	192.4905	19.089	0.06860	62.3541	8339	0.01823
1200	18.6030	17.6878	17.6878	82.6922	176.5095	17.518	0.06116	55.6867	7648	0.01482
1300	18.7781	19.5566	19.5566	84.1650	162.9888	16.178	0.04179	49.6890	7088	0.01180
1400	18.9122	21.4409	21.4409	85.5913	151.3893	15.083	0.03430	44.8122	6561	0.00970
1500	19.0270	23.3378	23.3378	86.8700	141.3330	14.039	0.02882	40.2285	6128	0.00785
1600	19.1228	25.2453	25.2453	88.1010	132.5298	13.169	0.02423	36.3918	5745	0.00609
1700	19.2035	27.1616	27.1616	89.2828	124.7591	12.400	0.02091	33.0067	5409	0.00450
1800	19.2720	29.0864	29.0864	90.3922	117.8493	11.717	0.01746	29.9938	5110	0.00343
1900	19.3306	31.0155	31.0155	91.4059	111.6650	11.105	0.01520	27.3014	4842	0.00280
2000	19.3813	32.9511	32.9511	92.3967	106.0973	10.554	0.01309	24.8764	4601	0.00235
2100	19.4262	34.8915	34.8915	93.3454	101.0585	10.055	0.01135	22.6821	4383	0.00203
2200	19.4655	36.8359	36.8359	94.2499	96.4707	9.601	0.00989	20.6870	4184	0.00177
2300	19.4971	38.7839	38.7839	95.1169	92.2924	9.188	0.00890	18.8662	4003	0.00158
2400	19.5268	40.7351	40.7351	95.9463	88.4560	8.806	0.00807	17.1959	3837	0.00143
2500	19.5532	42.6891	42.6891	96.7440	84.9258	8.466	0.00689	15.6583	3684	0.00128
2600	19.5766	44.6466	44.6466	97.5113	81.6666	8.133	0.00608	14.2397	3543	0.00118
2700	19.5976	46.6043	46.6043	98.2505	78.6483	7.833	0.00560	12.9260	3412	0.00113
2800	19.6165	48.5650	48.5650	98.9636	75.8432	7.555	0.00503	11.7081	3291	0.00107
2900	19.6332	50.5275	50.5275	99.6622	73.2350	7.296	0.00460	10.5702	3178	0.00100
3000	19.6486	52.4916	52.4916	100.3181	70.7985	7.054	0.00412	9.5100	3072	0.00093
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	0.00346	7.5882	2880	0.00087
3300	19.6867	58.3922	58.3922	102.1927	64.3736	6.416	0.00304	6.7146	2793	0.00083
3400	19.6972	60.3614	60.3614	102.7805	62.4834	6.228	0.00287	5.8923	2711	0.00083
3500	19.7069	62.3316	62.3316	103.3516	60.7011	6.051	0.00267	5.1169	2634	0.00068
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	57.4261	5.725	0.00232	3.6919	2492	0.00051
3800	19.7316	68.2475	68.2475	104.9738	55.9182	5.575	0.00211	3.0336	2427	0.00039
3900	19.7386	70.2210	70.2210	105.4860	54.4846	5.433	0.00185	2.4129	2365	0.00035
4000	19.7451	72.1952	72.1952	105.9868	53.1245	5.296	0.00171	1.8213	2306	0.00026
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	0.00161	0.7226	2196	0.00080
4300	19.7619	78.1213	78.1213	107.4144	49.4281	4.929	0.00167	0.2116	2145	0.00030
4400	19.7668	80.0977	80.0977	107.8688	48.3013	4.817	0.00146	0.0000	2097	0.00020
4500	19.7714	82.0746	82.0746	108.3130	47.2294	4.711	0.00127	0.0000	2050	0.00025
4600	19.7737	84.0519	84.0519	108.7476	46.2040	4.609	0.00116	-1.1833	2006	0.00019
4700	19.7777	86.0295	86.0295	109.1729	45.2222	4.512	0.00100	-1.6153	1963	0.00014
4800	19.7814	88.0074	88.0074	109.5893	44.2812	4.418	0.00097	-2.0244	1922	0.00026
4900	19.7849	89.9857	89.9857	109.9972	43.3756	4.326	0.00090	-2.4169	1883	0.00020
5000	19.7882	91.9644	91.9644	110.3970	42.5121	4.242	0.00084	-2.7967	1845	0.00024
5100	19.7913	93.9434	93.9434	110.7889	41.6798	4.169	0.00079	-3.1567	1809	0.00022
5200	19.7942	95.9226	95.9226	111.1732	40.8789	4.079	0.00078	-3.5038	1775	0.00009
5300	19.7969	97.9022	97.9022	111.5503	40.1085	4.002	0.00079	-3.8388	1741	0.00019
5400	19.7995	99.8820	99.8820	111.9204	39.3666	3.929	0.00064	-4.1614	1708	0.00025
5500	19.8020	101.8621	101.8621	112.2837	38.6516	3.857	0.00065	-4.4722	1678	0.00016
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	0.00058	-5.0612	1619	0.00016
5800	19.8089	107.8037	107.8037	113.3355	36.6546	3.659	0.00043	-5.3405	1591	0.00014
5900	19.8110	109.7847	109.7847	113.6742	36.0340	3.597	0.00040	-5.6103	1564	0.00013
6000	19.8131	111.7659	111.7659	114.0072	35.4341			-5.8711		

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TABLE XVI—THERMODYNAMIC PROPERTIES OF BH (GAS)

[Molecular weight, 11.828]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H _T ^o - H ₀ ^o ($\frac{\text{kcal}}{\text{mole}}$)	H _T ^o ($\frac{\text{kcal}}{\text{mole}}$)	S _T ^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^o}{RT}$	$\delta \left(\frac{-\Delta H^o}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$		log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0		0	279.8258							
288.16	6.9592	2.0739	281.8997	41.0362	127.4088			50.3050		
300	6.9566	2.0837	281.9125	41.0790	126.8364			49.9656		
400	6.9981	2.7839	282.6097	43.0847	95.8504			36.1918		
500	7.0796	3.4571	283.3129	44.6534	76.8727			27.8950		
600	7.2130	4.2014	284.0272	45.9554	64.0449			22.3429		
700	7.3713	4.8205	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	43.1123			13.0308		
1000	7.8309	7.2383	287.0391	49.7831	38.9114	3784	0.03127	11.1568	1667	0.02285
1100	7.9561	8.0028	287.8284	50.5404	35.4674	2417	0.02740	9.6175	1519	0.01927
1200	8.0658	8.8037	288.6296	51.2573	32.5925	1316	0.02419	8.3324	1295	0.01702
1300	8.1607	9.6150	289.4408	51.8967	30.1560	2899	0.02089	7.2423	1290	0.01507
1400	8.2431	10.4352	290.2610	52.4945	28.0644	2696	0.01807	6.3058	1200	0.01340
1500	8.3144	11.2631	291.0889	53.0536	26.2490	2520	0.01550	5.4924	1122	0.01185
1600	8.3764	12.0976	291.9234	53.5842	24.6585	2366	0.01344	4.7792	1054	0.01060
1700	8.4302	12.9380	292.7638	54.1136	23.2533	2229	0.01217	4.1486	993	0.00963
1800	8.4772	13.7833	293.6091	54.6408	22.0028	2108	0.01083	3.5871	939	0.00919
1900	8.5184	14.6331	294.4589	55.1662	20.8830	2000	0.00950	3.0837	891	0.00840
2000	8.5546	15.4868	295.3126	55.6941	19.8740	1902	0.00789	2.6298	848	0.00749
2100	8.5866	16.3438	296.1696	56.2123	18.9604	1818	0.00721	2.2185	809	0.00687
2200	8.6150	17.2039	297.0297	56.7124	18.1291	1733	0.00612	1.8439	773	0.00651
2300	8.6401	18.0667	297.8925	57.1959	17.3695	1659	0.00555	1.5013	740	0.00627
2400	8.6626	18.9318	298.7576	57.6641	16.6727	1591	0.00510	1.1567	710	0.00600
2500	8.6828	19.7991	299.6249	58.1181	16.0312	1529	0.00442	0.8960	682	0.00559
2600	8.7009	20.6683	300.4941	58.5790	15.4387	1471	0.00409	0.6289	657	0.00527
2700	8.7172	21.5392	301.3650	59.0377	14.8898	1418	0.00367	0.3803	633	0.00503
2800	8.7320	22.4116	302.2374	59.4940	14.3798	1368	0.00338	0.1492	611	0.00481
2900	8.7453	23.2855	303.1113	59.9476	13.9047	1322	0.00293	0.0663	590	0.00473
3000	8.7575	24.1606	303.9864	60.3983	13.4611	1279	0.00262	0.2677	571	0.00451
3100	8.7686	25.0369	304.8627	60.8456	13.0459	1238	0.00232	-0.4564	554	0.00408
3200	8.7788	25.9143	305.7401	61.2894	12.6565	1200	0.00206	-0.6336	537	0.00397
3300	8.7881	26.7926	306.6184	61.7298	12.2905	1164	0.00225	-0.8003	521	0.00386
3400	8.7966	27.6719	307.4977	62.1670	11.9469	1130	0.00204	-0.9574	506	0.00373
3500	8.8045	28.5519	308.3777	62.5921	11.6210	1099	0.00182	-1.1057	492	0.00363
3600	8.8117	29.4327	309.2585	63.0102	11.3139	1068	0.00185	-1.2460	479	0.00344
3700	8.8184	30.3143	310.1401	63.4217	11.0234	1040	0.00162	-1.3789	466	0.00347
3800	8.8246	31.1964	311.0222	63.8260	10.7481	1013	0.00156	-1.5050	454	0.00339
3900	8.8304	32.0792	311.9050	64.2233	10.4868	988	0.00130	-1.6248	443	0.00315
4000	8.8357	32.9625	312.7888	64.6139	10.2385	964	0.00118	-1.7387	432	0.00313
4100	8.8407	33.8463	313.6721	65.0018	10.0022	940	0.00119	-1.8472	422	0.00302
4200	8.8453	34.7306	314.5564	65.3873	9.7772	918	0.00111	-1.9507	412	0.00299
4300	8.8497	35.6153	315.4411	65.7704	9.5626	897	0.00114	-2.0495	403	0.00291
4400	8.8537	36.5005	316.3263	66.1512	9.3576	877	0.00091	-2.1440	394	0.00274
4500	8.8575	37.3861	317.2119	66.5291	9.1618	858	0.00088	-2.2343	386	0.00269
4600	8.8611	38.2720	318.0978	66.9046	8.9744	840	0.00078	-2.3209	378	0.00257
4700	8.8644	39.1583	318.9841	67.2772	8.7949	822	0.00075	-2.4039	370	0.00252
4800	8.8676	40.0449	319.8707	67.6473	8.6229	805	0.00072	-2.4835	363	0.00242
4900	8.8705	40.9318	320.7576	68.0148	8.4579	789	0.00060	-2.5600	356	0.00230
5000	8.8733	41.8190	321.6448	68.3796	8.2995	774	0.00054	-2.6335	349	0.00227
5100	8.8759	42.7064	322.5322	68.7418	8.1473	758	0.00063	-2.7042	342	0.00233
5200	8.8784	43.5941	323.4199	69.0913	8.0008	744	0.00052	-2.7723	336	0.00220
5300	8.8807	44.4821	324.3079	69.4383	7.8599	730	0.00052	-2.8379	330	0.00209
5400	8.8830	45.3703	325.1961	69.7828	7.7242	717	0.00044	-2.9011	325	0.00201
5500	8.8850	46.2587	326.0845	70.1243	7.5934	704	0.00039	-2.9622	319	0.00194
5600	8.8870	47.1473	326.9731	70.4624	7.4678	692	0.00040	-3.0211	313	0.00189
5700	8.8889	48.0361	327.8619	70.7973	7.3455	680	0.00026	-3.0780	308	0.00200
5800	8.8907	48.9251	328.7509	71.1294	7.2260	668	0.00028	-3.1331	303	0.00184
5900	8.8924	49.8142	329.6400	71.4588	7.1145	657	0.00030	-3.1863	296	0.00183
6000	8.8941	50.7035	330.5293	71.7858	7.0047			-3.2378		

TABLE XVII—THERMODYNAMIC PROPERTIES OF BO (GAS)

[Molecular weight, 26.82]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H ₂ - II ₂ ($\frac{\text{kcal}}{\text{mole}}$)	H ₂ ($\frac{\text{kcal}}{\text{mole}}$)	S ₂ ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^\circ}{RT}$	$\delta \left(\frac{\Delta H^\circ}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$		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	272.6996	-----	-----	112.6245	-----	-----
300	6.977	2.0849	170.2475	48.647	271.0072	-----	-----	111.8980	-----	-----
400	7.062	2.7872	170.9488	50.664	203.6499	-----	-----	82.4477	-----	-----
500	7.230	3.8018	171.6634	52.269	153.2146	-----	-----	64.7442	-----	-----
600	7.427	4.2847	172.3963	53.594	136.2389	-----	-----	52.9207	-----	-----
700	7.636	4.9880	173.1496	54.765	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	0.03692	29.1974	3547	0.02195
1100	8.225	8.1697	176.3313	58.3413	74.7951	7363	0.02847	25.9509	3229	0.01747
1200	8.325	8.9972	177.1688	59.0618	68.6326	6784	.02252	23.2426	2963	.01467
1300	8.411	9.8340	177.9956	59.7310	63.4149	6299	.01907	20.9457	2737	.01310
1400	8.485	10.6788	178.8404	60.3670	58.9394	5797	.01653	18.9806	2544	.01120
1500	8.5485	11.5305	179.6921	60.9446	55.0382	5414	.01425	17.2734	2378	.01010
1600	8.6025	12.3881	180.5497	61.4980	51.6602	5079	0.01196	15.7783	2229	0.00912
1700	8.6483	13.2506	181.4122	62.0209	48.6606	4788	.01048	14.4680	2099	.00839
1800	8.6883	14.1174	182.2790	62.5164	46.0929	4520	.00955	13.2835	1984	.00779
1900	8.7235	14.9866	183.1496	62.9871	43.8051	4284	.00900	12.2318	1880	.00720
2000	8.7560	15.8620	184.0236	63.4354	41.4582	4071	.00833	11.2846	1787	.00665
2100	8.7856	16.7389	184.9005	63.8632	39.5963	3879	0.00822	10.4270	1703	0.00611
2200	8.8095	17.6185	185.7801	64.2724	37.7398	3704	.00587	9.6468	1627	.00551
2300	8.8233	18.5007	186.6622	64.6645	36.1285	3545	.00492	8.9339	1566	.00547
2400	8.8349	19.3851	187.5467	65.0409	34.6415	3396	.00460	8.2801	1498	.00480
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	30.8623	3024	.00320	6.6069	1329	.00406
2800	8.9268	22.9421	191.1037	66.4116	29.7891	2918	.00249	6.1282	1282	.00393
2900	8.9421	23.8355	191.9971	66.7251	28.7804	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	26.9879	2638	0.00182	4.8769	1169	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	25.3369	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	197.3868	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	0.00293
3700	9.0430	31.0313	199.1929	68.9159	22.6607	2214	.00087	2.9765	973	.00285
3800	9.0543	31.9362	200.0978	69.1572	22.0977	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	-0.00049	2.0147	879	0.00261
4200	9.0976	35.5666	203.7282	70.0655	20.0131	1953	-0.00029	1.8026	859	.00243
4300	9.1080	36.4769	204.6385	70.2797	19.5592	1908	-0.0044	1.6006	839	.00242
4400	9.1183	37.3882	205.5496	70.4892	19.1260	1866	-0.0044	1.4075	820	.00238
4500	9.1284	38.3006	206.4622	70.6943	18.7120	1824	-0.0063	1.2229	802	.00235
4600	9.1384	39.2139	207.3755	70.8950	18.3161	1785	-0.0069	1.0462	785	0.00238
4700	9.1482	40.1282	208.2896	71.0916	17.9370	1747	-0.0076	.8766	768	.00230
4800	9.1579	41.0325	209.2051	71.2843	17.5738	1710	-0.0058	.7145	753	.00213
4900	9.1675	41.9386	210.1214	71.4733	17.2254	1676	-0.0070	.5667	738	.00210
5000	9.1769	42.8470	211.0386	71.6586	16.8909	1642	-0.0066	.4300	722	.00223
5100	9.1862	43.7562	211.9563	71.8404	16.5696	1610	-0.0072	0.2852	709	0.00215
5200	9.1954	44.6748	212.8759	72.0189	16.2607	1580	-0.0091	.1267	695	.00217
5300	9.2045	45.5943	213.7969	72.1941	15.9635	1550	-0.0084	-.0066	682	.00210
5400	9.2135	46.5152	214.7168	72.3662	15.6773	1521	-0.0085	-.1350	669	.00216
5500	9.2224	47.4370	215.6386	72.5354	15.4016	1494	-0.0099	-.2868	657	.00218
5600	9.2312	48.3596	216.5612	72.7016	15.1368	1467	-0.0077	-0.3783	645	0.00214
5700	9.2399	49.2832	217.4848	72.8651	14.8792	1441	-0.0085	-.4936	634	.00219
5800	9.2485	50.2076	218.4092	73.0259	14.6216	1416	-0.0080	-.6051	623	.00211
5900	9.2570	51.1329	219.3345	73.1840	14.3724	1393	-0.0097	-.7128	612	.00220
6000	9.2654	52.0590	220.2606	73.3397	14.1312	-----	-----	-.8170	-----	-----

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TABLE XVIII—THERMODYNAMIC PROPERTIES OF B₂O₃ (GAS)

[Molecular weight, 69.84]

T (°K)	C _p ^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H _f ^o -H ₀ ^o ($\frac{\text{kcal}}{\text{mole}}$)	H _f ^o ($\frac{\text{kcal}}{\text{mole}}$)	S _f ^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^o}{RT}$	$\ln\left(\frac{\Delta H^o}{RT}\right) - \frac{-dT}{100}\left(\frac{a}{T}+b\right)$		log K	$\delta \log K = \frac{-\delta T}{100}\left(\frac{c}{T}+d\right)$	
						a	b		c	d
0	-----	0	126.0889	-----	-----	-----	-----	-----	-----	-----
298.16	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
300	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
400	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
500	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
600	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
700	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
800	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
900	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1000	28.390	16.5945	142.6894	82.1636	301.8037	29.998	0.10329	101.1271	13.090	0.01700
1100	28.754	18.9502	148.0391	84.4085	274.4295	27.265	0.08117	89.2101	11.905	0.01197
1200	24.084	21.3411	147.4300	86.4886	261.6026	26.041	-.06409	79.2773	10.917	-.00821
1300	24.311	23.7899	149.8488	88.4246	232.2761	23.131	-.05178	70.8714	10.081	-.00498
1400	24.510	26.2009	162.2898	90.2335	216.7022	21.492	-.04230	63.6657	9.363	-.00340
1500	24.672	28.6900	164.7489	91.9300	201.3319	20.071	-.03442	57.4203	8.741	-.00178
1600	24.806	31.1339	187.2228	93.5266	188.7631	18.826	0.02917	51.9554	8.196	0.00092
1700	24.916	33.6199	169.7088	95.0337	177.6604	17.726	-.02422	47.1333	7.715	-.00099
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	25.169	41.1337	167.2226	99.1036	150.9896	15.083	-.01532	35.5908	6.560	-.00131
2100	25.221	43.6527	169.7416	100.3326	143.7919	14.368	0.01369	32.4383	6.248	-.00160
2200	25.277	46.1778	172.2665	101.6071	137.2473	13.718	-.01235	29.5999	5.965	-.00198
2300	25.329	48.7079	174.7998	102.8319	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	104.7473	120.7492	12.087	-.00563	22.4480	5.249	-.00196
2600	25.439	56.3245	182.4134	105.7445	116.0947	11.626	0.00418	20.4311	5.047	-.00196
2700	25.466	58.8697	184.9586	106.7060	111.7846	11.197	-.00367	18.5633	4.861	-.00227
2800	25.491	61.4176	187.6065	107.6316	107.7820	10.802	-.00177	16.8300	4.687	-.00221
2900	25.514	63.9678	190.0587	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	-.00065	12.3008	4.233	-.00201
3200	25.570	71.6306	197.7195	111.0409	94.2728	9.463	-.00197	10.9600	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	86.1676	8.659	-.00418	7.4712	3.748	-.00161
3600	25.624	81.8700	207.9589	114.0560	83.7664	8.420	-.00447	6.4317	3.644	-.00166
3700	25.635	84.4330	210.5219	114.7582	81.4952	8.195	-.00528	5.4485	3.546	-.00159
3800	25.645	86.9970	213.0859	115.4419	79.3439	7.980	-.00533	4.5172	3.452	-.00163
3900	25.655	89.5620	215.6509	116.1082	77.3031	7.779	-.00635	3.6336	3.362	-.00130
4000	25.663	92.1279	218.2188	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	-.00664	1.9961	3.198	-.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	-.00808	-1.4740	2.849	-.00087
4700	25.710	110.1099	236.1988	120.9005	64.1185	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	-3.2168	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	59.0776	5.956	-.00828	-4.2620	2.568	-.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	125.4065	53.8009	5.423	-.00800	-6.5638	2.337	-.00010
5700	25.752	135.8424	261.9313	125.8643	52.8675	5.327	-.00785	-6.9937	2.295	-.00011
5800	25.756	138.4178	264.5067	126.3122	51.9469	5.235	-.00759	-7.3995	2.256	-.00020
5900	25.760	140.9936	267.0825	126.7625	51.0675	5.145	-.00810	-7.7419	2.216	-.00027
6000	25.763	143.5698	269.6587	127.1853	50.2176	5.055	-----	-8.1115	-----	-----

TABLE XIX—THERMODYNAMIC PROPERTIES OF B₂O₃ (CRYSTAL)

[Molecular weight, 69.84]

T (°K)	C _p ^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H _f ^o -H ₀ ^o ($\frac{\text{kcal}}{\text{mole}}$)	H _f ^o ($\frac{\text{kcal}}{\text{mole}}$)	S _f ^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^o}{RT}$	log K
0	-----	0	48.6839	-----	-----	-----
298.16	14.73	2.2410	50.9249	13.07	1137.338	455.534
300	14.79	2.2690	50.9519	13.16	1130.890	452.523
400	18.40	3.0240	52.6079	17.90	848.915	329.717
500	21.12	5.9080	54.5919	22.31	679.678	255.953
600	23.26	8.1300	56.8139	26.36	568.642	206.747
700	25.15	10.6520	59.2359	30.09	486.753	171.689
723.16	26.57	11.1400	59.8239	30.91	470.191	164.833

TABLE XX—THERMODYNAMIC PROPERTIES OF B₂O₃ (LIQUID)

[Molecular weight, 69.64]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H _T ^o -H ₀ ^o ($\frac{\text{kcal}}{\text{mole}}$) (*)	H _T ^o ($\frac{\text{kcal}}{\text{mole}}$)	S _T ^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^o}{RT}$	$\delta \left(-\frac{\Delta H^o}{RT} - \frac{-\delta T}{100} \left(\frac{a}{T^2} + b \right) \right)$		log K	$\delta \log K - \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
723.16	31.75	18.5600	65.2439	38.41	466.420	-----	-----	164.838	-----	-----
800	31.660	18.9962	67.6801	41.6117	421.294	-----	-----	145.384	-----	-----
900	31.242	22.1413	70.8252	45.3188	374.121	-----	-----	126.064	-----	-----
1000	30.835	25.2452	73.8291	48.5872	336.4027	34.014	-0.07512	108.8151	14.670	-0.06036
1100	30.680	28.3159	76.9998	51.5141	306.5360	30.893	-0.04637	95.5391	13.333	-0.05693
1200	30.442	31.3670	80.0509	54.1690	279.8582	28.291	-0.02131	84.4852	12.216	-0.05142
1300	30.392	34.4067	83.0926	56.6037	258.1172	26.095	-0.00489	75.1397	11.271	-0.04681
1400	30.377	37.4472	86.1311	58.8554	239.4828	24.226	-0.00097	67.1358	10.482	-0.04377
1500	30.372	40.4846	89.1685	60.9511	223.8331	22.610	-0.00015	60.2049	9.760	-0.04040
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	-0.00049	48.8090	8.605	-0.03585
1800	30.370	49.5957	98.2796	66.4882	185.6800	18.842	-0.00024	44.0583	8.123	-0.03346
1900	30.370	52.6327	101.3166	68.1308	175.7334	17.851	-0.00030	39.8165	7.692	-0.03150
2000	30.370	55.6697	104.3536	69.6880	166.8082	16.938	-0.00024	36.0020	7.304	-0.02980
2100	30.370	58.7067	107.3906	71.1698	158.7332	16.151	-0.00036	32.5588	6.964	-0.02861
2200	30.370	61.7437	110.4276	72.5826	151.3922	15.416	-0.00011	29.4215	6.685	-0.02738
2300	30.370	64.7807	113.4646	73.9326	144.6897	14.746	-0.00027	26.5641	6.344	-0.02613
2400	30.370	67.8177	116.5016	75.2251	138.5458	14.131	-0.00010	23.9459	6.077	-0.02500
2500	30.370	70.8547	119.5386	76.4649	132.8685	-----	-----	21.5411	-----	-----

* Enthalpy change in converting B₂O₃ (crystal) at 0° K to B₂O₃ (liquid) at temperature indicated.

TABLE XXI—THERMODYNAMIC PROPERTIES OF C (GAS)

[Atomic weight, 12.010]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H _T ^o -H ₀ ^o ($\frac{\text{kcal}}{\text{mole}}$)	H _T ^o ($\frac{\text{kcal}}{\text{mole}}$)	S _T ^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)
0	-----	0	262.3181	-----
298.16	4.9808	1.5089	263.8770	37.7611
300	4.9801	1.5651	263.8832	37.7617
400	4.9747	2.0858	264.9839	39.2235
500	4.9723	2.6331	264.8612	40.3353
600	4.9709	3.0603	265.3784	41.2398
700	4.9701	3.5573	265.8754	42.0080
800	4.9697	4.0543	266.3724	42.6996
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	44.2621
1200	4.9697	6.0421	268.3602	44.6846
1300	4.9705	6.5391	268.8572	45.0828
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	271.8456	46.9720
2000	5.0075	10.0277	272.3458	47.2287
2100	5.0189	10.5290	272.8471	47.4732
2200	5.0316	11.0316	273.3496	47.7070
2300	5.0455	11.5354	273.8536	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	14.0786	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	49.4582
3200	5.2056	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	17.7158	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	282.6856	50.7982
4100	5.3599	20.9026	283.2207	50.9303
4200	5.3752	21.4392	283.7573	51.0596
4300	5.3898	21.9772	284.2953	51.1862
4400	5.3994	22.5165	284.8347	51.3102
4500	5.4116	23.0570	285.3751	51.4317
4600	5.4227	23.5987	285.9168	51.5506
4700	5.4331	24.1416	286.4596	51.6675
4800	5.4427	24.6853	287.0034	51.7820
4900	5.4514	25.2300	287.5481	51.8943
5000	5.4592	25.7756	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	5.4866	29.0608	291.3789	52.6250
5700	5.4882	29.6096	291.9277	52.7221
5800	5.4893	30.1586	292.4768	52.8176
5900	5.4898	30.7074	293.0265	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 ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H _T ^o -H ₀ ^o ($\frac{\text{kcal}}{\text{mole}}$)	H _T ^o ($\frac{\text{kcal}}{\text{mole}}$)	S _T ^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^o}{RT}$	$\delta \left(\frac{\Delta H^o}{RT} \right) = -\frac{\delta T}{100} \left(\frac{a}{T} + b \right)$		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	494.2122	-----	-----	182.2536	-----	-----
300	6.965	2.0855	67.8316	47.342	491.5591	-----	-----	181.0967	-----	-----
400	7.018	2.7838	68.5299	49.352	324.0685	-----	-----	134.2147	-----	-----
500	7.120	3.4900	69.2861	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	185.7981	-----	-----	73.8126	-----	-----
800	7.624	5.6998	71.4459	54.379	162.7222	-----	-----	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	0.08349	49.5787	5640	0.02293
1100	8.058	8.0580	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	.02634	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	76.2687	58.8569	93.4014	9.235	.01733	33.3754	4038	.01310
1500	8.419	11.3580	77.1041	59.4363	87.2374	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	77.0590	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	80.5196	61.4510	69.0165	6.820	.00720	22.6868	2982	.00830
2000	8.665	15.6351	81.3812	61.8945	65.5983	6.482	.00563	21.1873	2834	.00748
2100	8.699	16.5033	82.2494	62.3181	62.5060	6.176	0.00443	19.3308	2700	0.00693
2200	8.730	17.3747	83.1208	62.7234	59.6943	5.896	.00325	18.5966	2578	.00653
2300	8.758	18.2491	83.9952	63.1121	57.1267	5.644	.00213	17.4692	2467	.00608
2400	8.784	19.1262	84.8723	63.4854	54.7729	5.412	.00100	16.4352	2366	.00580
2500	8.806	20.0067	85.7518	63.8444	52.6073	5.197	.00026	15.4834	2271	.00544
2600	8.827	20.8874	86.6335	64.1902	50.6082	4.999	-0.00048	14.6043	2184	0.00531
2700	8.847	21.7711	87.5172	64.5238	48.7672	4.815	-0.00084	13.7903	2104	.00507
2800	8.865	22.6567	88.4028	64.8458	47.0884	4.645	-0.00163	13.0338	2029	.00494
2900	8.882	23.5440	89.2901	65.1572	45.4833	4.486	-0.00203	12.3292	1959	.00490
3000	8.898	24.4330	90.1791	65.4586	43.9450	4.338	-0.00236	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	26.2196	91.9627	66.0338	41.2387	4.070	-0.00358	10.4779	1777	.00432
3300	8.939	27.1099	92.8560	66.3087	40.0089	3.948	-0.00339	9.9351	1723	.00444
3400	8.952	28.0044	93.7505	66.5757	38.8517	3.832	-0.00386	9.4239	1673	.00420
3500	8.963	28.9002	94.6463	66.8354	37.7607	3.722	-0.00417	8.9417	1626	.00403
3600	8.974	29.7970	95.5431	67.0890	36.7307	3.619	-0.00391	8.4900	1580	0.00417
3700	8.985	30.6950	96.4411	67.3340	35.7665	3.523	-0.00414	8.0548	1538	.00406
3800	8.995	31.5940	97.3401	67.5738	34.8338	3.429	-0.00403	7.6400	1498	.00390
3900	9.005	32.4940	98.2401	67.8076	33.9358	3.341	-0.00405	7.2580	1460	.00390
4000	9.015	33.3950	99.1411	68.0357	33.1274	3.258	-0.00423	6.8992	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	100.9469	68.4760	31.5844	3.103	-0.00423	6.2037	1356	.00365
4300	9.042	36.1036	101.8497	68.6887	30.8670	3.030	-0.00394	5.8947	1325	.00368
4400	9.051	37.0083	102.7544	68.8966	30.1823	2.961	-0.00400	5.5799	1295	.00362
4500	9.059	37.9138	103.6599	69.1001	29.5283	2.895	-0.00395	5.2886	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	-0.00358	4.7425	1213	.00349
4800	9.082	40.6349	106.3810	69.6855	27.7308	2.712	-0.00347	4.4863	1187	.00356
4900	9.089	41.5435	107.2896	69.8728	27.1898	2.653	-0.00310	4.2405	1164	.00340
5000	9.096	42.4527	108.1988	70.0566	26.6529	2.601	-0.00300	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	-0.00261	3.5689	1097	.00332
5300	9.117	45.1847	110.9308	70.5872	25.1896	2.451	-0.00239	3.3486	1077	.00326
5400	9.123	46.0967	111.8428	70.7576	24.7381	2.403	-0.00201	3.1459	1057	.00322
5500	9.129	47.0093	112.7554	70.9251	24.3032	2.358	-0.00167	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	-0.00140	2.5799	1001	.00321
5800	9.150	49.7513	115.4974	71.4105	23.0887	2.234	-0.00135	2.4041	984	.00322
5900	9.156	50.6666	116.4127	71.5670	22.7114	2.196	-0.00130	2.2341	968	.00317
6000	9.162	51.5825	117.3286	71.7209	22.3467	-----	-----	2.0696	-----	-----

TABLE XXII—THERMODYNAMIC PROPERTIES OF CO₂ (GAS)

[Molecular weight, 44.010]

T (°K)	C _p (cal/mole °K)	H _f - H _f ⁰ (kcal/mole)	H _f (kcal/mole)	S _f (cal/mole °K)	ΔH ⁰ FT	d ($\frac{\Delta^{\circ}H}{RT} = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$)		log K	ε 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	2.2646	2.2646	51.116	644.2627			265.8787		
400	9.871	3.1948	3.1948	53.815	483.0369			193.5795		
500	10.862	4.2228	4.2228	56.113	287.6422			153.8214		
600	11.811	5.3224	5.3224	58.109	323.3782			125.7489		
700	11.849	6.4813	6.4813	59.895	277.4307			105.6761		
800	12.800	7.6894	7.6894	61.507	242.9362			90.8086		
900	12.678	8.9399	8.9399	62.980	216.0824			78.8821		
1000	12.995	10.2220	10.2220	64.3310	194.8323	19.268	0.07095	69.4963	8428	0.02258
1100	13.265	11.5360	11.5360	66.5822	176.9768	17.548	0.05867	61.8111	7866	0.01797
1200	13.490	12.8728	12.8728	68.7461	162.2948	16.097	0.04919	55.4048	7081	0.01434
1300	13.680	14.2312	14.2312	67.8334	149.8633	14.568	0.04210	49.9820	6494	0.01103
1400	13.844	15.6074	15.6074	68.8632	139.2012	13.814	0.03947	45.3324	6083	0.00880
1500	13.988	16.9990	16.9990	69.8132	129.9554	12.900	0.03180	41.3016	5633	0.00718
1600	14.116	18.4042	18.4042	70.7200	121.8611	12.100	0.02796	37.7788	5283	0.00585
1700	14.230	19.8216	19.8216	71.5792	114.7156	11.395	0.02694	34.6603	4974	0.00467
1800	14.331	21.2496	21.2496	72.3955	108.3610	10.767	0.02116	31.8923	4699	0.00394
1900	14.421	22.6872	22.6872	73.1727	102.6730	10.206	0.01820	29.4162	4453	0.00320
2000	14.502	24.1334	24.1334	73.9145	97.5618	9.701	0.01548	27.1856	4221	0.00274
2100	14.576	25.5872	25.5872	74.6238	92.9188	9.244	0.01318	25.1680	4030	0.00248
2200	14.643	27.0482	27.0482	75.3084	88.7018	8.828	0.01124	23.3337	3848	0.00196
2300	14.705	28.5166	28.5166	75.9587	84.8523	8.447	0.01002	21.6587	3681	0.00175
2400	14.763	29.9890	29.9890	76.6828	81.3227	8.099	0.00850	20.1232	3529	0.00120
2500	14.817	31.4680	31.4680	77.4835	78.0748	7.778	0.00716	18.7104	3388	0.00112
2600	14.868	32.9522	32.9522	77.7897	75.0759	7.482	0.00599	17.4682	3258	0.00093
2700	14.916	34.4414	34.4414	78.3307	72.2688	7.208	0.00491	16.1986	3138	0.00089
2800	14.961	35.9353	35.9353	78.8740	69.7196	6.965	0.00322	15.0772	3026	0.00085
2900	15.003	37.4335	37.4335	79.3997	67.3181	6.717	0.00260	14.0381	2922	0.00080
3000	15.043	38.9358	38.9358	79.9090	65.0768	6.496	0.00172	13.0685	2825	0.00041
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	0.00043	11.2921	2649	0.00027
3300	15.152	43.4654	43.4654	81.3480	59.1661	5.912	0.00052	10.4891	2568	0.00051
3400	15.185	44.9822	44.9822	81.8008	57.4278	5.740	0.00100	9.7333	2493	0.00031
3500	15.216	46.5022	46.5022	82.2414	55.7888	5.573	0.00154	9.0207	2421	0.00050
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	0.00257	7.7110	2290	0.00047
3800	15.302	51.0802	51.0802	83.4963	51.3899	5.141	0.00250	7.1079	2230	0.00051
3900	15.329	52.6118	52.6118	83.8941	50.0742	5.011	0.00295	6.5366	2173	0.00045
4000	15.355	54.1460	54.1460	84.2826	48.8244	4.886	0.00311	5.9919	2119	0.00087
4100	15.380	55.6828	55.6828	84.6620	47.6368	4.767	0.00310	5.4747	2067	0.00046
4200	15.405	57.2220	57.2220	85.0329	46.5039	4.654	0.00322	4.9821	2018	0.00040
4300	15.429	58.7637	58.7637	85.3957	45.4248	4.546	0.00318	4.5124	1970	0.00057
4400	15.452	60.3078	60.3078	85.7507	44.3948	4.443	0.00333	4.0641	1926	0.00050
4500	15.476	61.8541	61.8541	86.0982	43.4106	4.343	0.00313	3.6356	1883	0.00055
4600	15.496	63.4028	63.4028	86.4386	42.4806	4.249	0.00314	3.2257	1842	0.00049
4700	15.520	64.9536	64.9536	86.7721	41.6089	4.158	0.00305	2.8333	1803	0.00048
4800	15.542	66.5068	66.5068	87.0991	40.7957	4.070	0.00271	2.4572	1765	0.00060
4900	15.564	68.0620	68.0620	87.4198	39.8773	3.986	0.00250	2.0964	1729	0.00068
5000	15.586	69.6196	69.6196	87.7344	39.0831	3.905	0.00239	1.7500	1694	0.00064
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	37.5856	3.752	0.00172	1.0971	1629	0.00064
5300	15.652	74.3052	74.3052	88.6445	36.8796	3.680	0.00158	0.7891	1598	0.00087
5400	15.674	75.8716	75.8716	88.9373	36.1997	3.610	0.00116	0.4925	1568	0.00071
5500	15.696	77.4400	77.4400	89.2251	35.5445	3.543	0.00088	0.2067	1540	0.00070
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	0.00037	-0.3350	1486	0.00069
5800	15.762	82.1588	82.1588	90.0604	33.7146	3.356	0.00031	-0.5919	1460	0.00074
5900	15.784	83.7360	83.7360	90.3301	33.1461	3.298	0.00007	-0.8401	1435	0.00073
6000	15.806	85.3156	85.3156	90.5955	32.5965			-1.0500		

TABLE XXIV—THERMODYNAMIC PROPERTIES OF
Cl (GAS)

[Atomic weight, 35.457]

T (°K)	C_p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$H_T - H_0$ ($\frac{\text{kcal}}{\text{mole}}$)	H_T ($\frac{\text{kcal}}{\text{mole}}$)	S_T ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)
0	-----	0	32.5131	-----
298.16	5.2203	1.4961	34.0122	39.4569
300	5.2237	1.5057	34.0218	39.4890
400	5.3705	2.0391	34.5529	41.0138
500	5.4368	2.5301	35.0222	42.2206
600	5.4448	3.1244	35.6375	43.2132
700	5.4232	3.6880	36.1811	44.0511
800	5.3887	4.2066	36.7217	44.7731
900	5.3506	4.7456	37.2537	45.4056
1000	5.3133	5.2738	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	48.4263
1700	5.1392	8.9288	41.4417	48.7383
1800	5.1246	9.4418	41.9549	49.0216
1900	5.1117	9.9536	42.4667	49.2863
2000	5.1002	10.4642	42.9773	49.5302
2100	5.0900	10.9737	43.4868	49.8188
2200	5.0809	11.4823	43.9954	50.0854
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	51.2768
2900	5.0380	15.0222	47.5353	51.4527
3000	5.0339	15.5258	48.0389	51.6204
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	5.0205	17.5365	50.0496	52.2523
3500	5.0179	18.0385	50.5515	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	52.8103
3900	5.0089	20.0437	52.5568	52.9406
4000	5.0070	20.5445	53.0574	53.0674
4100	5.0052	21.0452	53.5578	53.1910
4200	5.0035	21.5456	54.0577	53.3116
4300	5.0020	22.0459	54.5570	53.4293
4400	5.0006	22.5460	55.0559	53.5443
4500	4.9993	23.0460	55.5545	53.6566
4600	4.9981	23.5459	56.0529	53.7666
4700	4.9970	24.0456	56.5507	53.8740
4800	4.9960	24.5453	57.0483	53.9792
4900	4.9950	25.0448	57.5457	54.0822
5000	4.9941	25.5443	58.0429	54.1831
5100	4.9932	26.0436	58.5397	54.2820
5200	4.9924	26.5429	59.0360	54.3789
5300	4.9916	27.0421	59.5318	54.4740
5400	4.9908	27.5412	60.0272	54.5673
5500	4.9901	28.0403	60.5224	54.6589
5600	4.9894	28.5393	61.0172	54.7488
5700	4.9887	29.0382	61.5115	54.8371
5800	4.9880	29.5370	62.0053	54.9239
5900	4.9873	30.0358	62.4987	55.0091
6000	4.9866	30.5345	63.0476	55.0929

TABLE XXV—THERMODYNAMIC PROPERTIES OF Cl₂ (GAS)

[Molecular weight, 70.914]

T (°K)	C _p (cal/mole °K)	H _T - H ₀ (kcal/mole)	H _T (kcal/mole)	S _T (cal/mole °K)	ΔH° RT	s(ΔH°/RT) - ΔT(a/T + b)		log K	Δ log K = -ΔT(c/T + d)	
						α	b		c	d
0	-----	0	7.8081	-----	-----	-----	-----	-----	-----	-----
298.16	8.11	2.1939	10.0000	53.236	97.3319	-----	-----	36.9304	-----	-----
300	8.12	2.2089	10.0150	53.336	97.3383	-----	-----	36.6695	-----	-----
400	8.44	3.0384	10.8445	56.720	73.2947	-----	-----	26.0820	-----	-----
500	8.62	3.8920	11.6981	57.625	58.9656	-----	-----	19.7044	-----	-----
600	8.74	4.7610	12.5671	59.207	49.2389	-----	-----	15.4354	-----	-----
700	8.82	5.6399	13.4460	60.662	42.3545	-----	-----	12.3755	-----	-----
800	8.88	6.5248	14.3269	61.744	37.1857	-----	-----	10.0725	-----	-----
900	8.92	7.4142	15.2203	62.792	33.1554	-----	-----	8.2757	-----	-----
1000	8.96	8.3090	16.1161	63.760	29.9262	2834	0.02478	6.8337	1282	0.01765
1100	8.99	9.2085	17.0126	64.6604	27.2796	2624	0.02283	5.6606	1168	0.01517
1200	9.02	10.1070	17.9131	65.5739	25.0701	2410	.01895	4.6821	1073	.01312
1300	9.04	11.0100	18.8161	66.4937	23.1973	2227	.01719	3.8236	992	.01153
1400	9.06	11.9150	19.7211	67.4264	21.6894	2070	.01570	3.1032	923	.01047
1500	9.08	12.8220	20.6281	67.3631	20.1937	1880	.01695	2.4774	863	.00923
1600	9.109	13.7315	21.5376	67.9600	18.9705	1817	0.01228	1.9288	810	0.00863
1700	9.124	14.6431	22.4492	68.5327	17.8894	1712	.01109	1.4437	764	.00786
1800	9.139	15.5663	23.3624	69.0547	16.9272	1618	.01042	1.0116	722	.00720
1900	9.155	16.4709	24.2770	69.5192	16.0652	1534	.00990	.6244	686	.00660
2000	9.171	17.3873	25.1934	70.0192	15.2883	1460	.00856	.2752	653	.00615
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	13.3685	1272	.00740	-.5928	570	.00440
2400	9.230	21.0673	28.8734	71.6934	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	72.4334	11.8687	1128	0.00632	-1.2637	506	0.00359
2700	9.273	23.8427	31.6488	72.7860	11.4446	1067	.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	.00537	-1.7979	456	.00280
3000	9.315	26.6309	34.4370	73.7662	10.3397	951	.00496	-1.9527	441	.00264
3100	9.327	27.5629	35.3690	74.0708	10.0183	949	0.00514	-2.0976	427	0.00256
3200	9.341	28.4963	36.3024	74.3672	9.7168	910	.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	40.0466	75.4706	8.6746	819	0.00455	-2.7085	371	0.00163
3700	9.409	33.1839	40.9800	75.7281	8.4487	798	.00430	-2.8054	361	.00160
3800	9.422	34.1254	41.9315	75.9792	8.2344	778	.00453	-2.9020	352	.00144
3900	9.436	35.0683	42.8744	76.2241	8.0309	758	.00410	-2.9987	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	76.9245	7.4773	708	.00481	-3.2432	319	.00131
4300	9.488	38.8526	46.6589	77.1479	7.3095	688	.00694	-3.3187	312	.00129
4400	9.501	39.8023	47.6084	77.3682	7.1492	672	.00697	-3.3909	305	.00122
4500	9.514	40.7530	48.5591	77.5798	6.9959	658	.00360	-3.4599	299	.00116
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	46.4858	54.2909	78.7754	6.1988	581	0.00377	-3.8181	265	0.00084
5200	9.606	47.4447	55.2506	78.9618	6.0833	569	.00384	-3.8699	260	.00084
5300	9.619	48.4069	56.2120	79.1449	5.9721	558	.00378	-3.9196	255	.00078
5400	9.632	49.3694	57.1745	79.3248	5.8645	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	79.6756	5.6614	530	0.00362	-4.0588	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 (cal/mole °K)	H _T ^o -H ₀ ^o (kcal/mole)	H _T ^o (kcal/mole)	S _T ^o (cal/mole °K)	ΔH _T ^o RT	s (-ΔH _T ^o /RT) = -dT(a/T+b)		log K	Δ log K = -dT(c/T+d)	
						a	b		c	d
0		0	21.2069							
298.16	7.6517	2.1281	23.3350	52.0433	102.1326			38.5196		
300	7.6599	2.1422	23.3491	52.0904	101.5154			38.5476		
400	8.0382	2.3283	24.1851	54.3491	79.4945			37.5018		
500	8.2920	3.7456	24.9525	56.1720	61.4528			20.5444		
600	8.4594	4.5838	25.7907	57.6997	51.4044			18.3882		
700	8.5723	5.4587	26.6426	59.0127	44.2125			13.1937		
800	8.6511	6.2971	27.5040	60.1628	38.8081			10.7896		
900	8.7077	7.1682	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	2742	0.01730	6.1757	1218	0.01020
1200	8.8060	9.7940	31.0009	63.7055	26.1804	2522	0.01490	5.1445	1119	0.01383
1300	8.8255	10.6766	31.8825	64.4111	24.1955	2331	0.01260	4.2699	1035	0.01211
1400	8.8411	11.5589	32.7658	65.0657	22.5180	2167	0.01073	3.5185	962	0.01127
1500	8.8538	12.4437	33.6506	65.6761	21.0226	2025	0.00908	2.8559	900	0.00980
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	0.00596	1.7875	796	0.00845
1800	8.8808	15.1042	36.3111	67.2929	17.6408	1692	0.00461	1.3368	753	0.00778
1900	8.8875	15.9928	37.1995	67.7733	16.7241	1605	0.00340	0.9227	714	0.00730
2000	8.8937	16.8817	38.0886	68.2293	15.9066	1525	0.00241	0.5684	680	0.00649
2100	8.8997	17.7713	38.9782	68.6634	15.2255	1453	0.00165	0.2381	648	0.00575
2200	8.9059	18.6616	39.8685	69.0775	14.6604	1388	0.00112	0.0628	619	0.00507
2300	8.9126	19.5525	40.7604	69.4736	13.9928	1327	0.00088	0.0000	593	0.00452
2400	8.9202	20.4442	41.6511	69.8530	13.3954	1272	0.00072	0.0000	569	0.00400
2500	8.9291	21.3366	42.5435	70.2174	12.8823	1220	0.00062	0.0000	547	0.00352
2600	8.9398	22.2301	43.4370	70.5678	12.4403	1173	0.00056	-0.0089	527	0.00310
2700	8.9525	23.1247	44.3316	70.9054	11.9991	1128	0.00050	-0.0237	508	0.00270
2800	8.9678	24.0207	45.2276	71.2313	11.5909	1086	0.00045	-0.0445	490	0.00230
2900	8.9858	24.9184	46.1253	71.5463	11.1894	1047	0.00040	-0.0650	474	0.00190
3000	9.0072	25.8180	47.0249	71.8513	10.8249	1009	0.00036	-0.0864	459	0.00150
3100	9.0320	26.7200	47.9269	72.1470	10.4918	974	0.00032	-0.1115	445	0.00110
3200	9.0606	27.6246	48.8315	72.4342	10.1791	941	0.00028	-0.1415	432	0.00070
3300	9.0932	28.5323	49.7392	72.7135	9.8848	909	0.00025	-0.1761	419	0.00030
3400	9.1299	29.4435	50.6504	72.9855	9.6073	879	0.00022	-0.2144	408	0.00000
3500	9.1709	30.3585	51.5654	73.2508	9.3450	850	0.00020	-0.2567	397	0.00000
3600	9.2162	31.2779	52.4848	73.5096	9.0966	823	0.00017	-0.3030	387	0.00000
3700	9.2658	32.2020	53.4089	73.7630	8.8610	797	0.00015	-0.3533	377	0.00000
3800	9.3197	33.1312	54.3381	74.0106	8.6371	772	0.00013	-0.4075	368	0.00000
3900	9.3778	34.0661	55.2730	74.2536	8.4238	749	0.00011	-0.4656	359	0.00000
4000	9.4399	35.0070	56.2139	74.4918	8.2205	726	0.00010	-0.5274	351	0.00000
4100	9.5059	35.9543	57.1612	74.7257	8.0263	705	0.00009	-0.5929	343	0.00000
4200	9.5754	36.9084	58.1153	74.9556	7.8404	684	0.00008	-0.6621	336	0.00000
4300	9.6485	37.8696	59.0765	75.1818	7.6624	666	0.00007	-0.7341	329	0.00000
4400	9.7246	38.8382	60.0451	75.4045	7.4915	647	0.00006	-0.8090	322	0.00000
4500	9.8035	39.8146	61.0215	75.6239	7.3274	630	0.00005	-0.8867	316	0.00000
4600	9.8849	40.7990	62.0059	75.8403	7.1696	614	0.00004	-0.9671	310	0.00000
4700	9.9686	41.7917	62.9986	76.0538	7.0175	599	0.00003	-1.0501	305	0.00000
4800	10.0539	42.7928	63.9997	76.2645	6.8709	585	0.00002	-1.1356	299	0.00000
4900	10.1407	43.8026	65.0095	76.4727	6.7293	572	0.00001	-1.2236	294	0.00000
5000	10.2287	44.8210	66.0279	76.6785	6.5926	560	0.00000	-1.3140	289	0.00000
5100	10.3173	45.8483	67.0552	76.8819	6.4603	548	0.00000	-1.4069	284	0.00000
5200	10.4064	46.8845	68.0914	77.0831	6.3322	538	0.00000	-1.5021	280	0.00000
5300	10.4955	47.9296	69.1365	77.2822	6.2081	528	0.00000	-1.6005	275	0.00000
5400	10.5844	48.9836	70.1905	77.4792	6.0878	519	0.00000	-1.7021	270	0.00000
5500	10.6728	50.0465	71.2534	77.6742	5.9710	511	0.00000	-1.8069	267	0.00000
5600	10.7597	51.1181	72.3250	77.8673	5.8576	504	0.00000	-1.9140	263	0.00000
5700	10.8457	52.1983	73.4052	78.0585	5.7474	497	0.00000	-2.0233	259	0.00000
5800	10.9302	53.2871	74.4940	78.2478	5.6403	491	0.00000	-2.1348	255	0.00000
5900	11.0129	54.3848	75.5912	78.4354	5.5361	485	0.00000	-2.2484	252	0.00000
6000	11.0937	55.4896	76.6965	78.6212	5.4346	480	0.00000	-2.3641	249	0.00000

TABLE XXVII—THERMODYNAMIC PROPERTIES OF F (GAS)

[Molecular weight, 19.00]

T (°K)	C_p ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)	$H_f - H_f^0$ ($\frac{\text{kcal}}{\text{mole}}$)	H_f ($\frac{\text{kcal}}{\text{mole}}$)	S_f ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)
0	-----	0	48.2781	-----
298.16	5.4864	1.5580	49.8361	37.9173
300	5.4855	1.6080	49.8401	37.9507
400	5.5612	2.1081	50.3882	39.8060
500	5.2819	2.6401	50.9182	40.6929
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	43.1879
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	46.3282
1600	5.0181	8.2468	56.5249	46.6493
1700	5.0129	8.7483	57.0264	46.9334
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

REPORT 1037—NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TABLE XXVIII—THERMODYNAMIC PROPERTIES OF F₂ (GAS)

[Molecular weight, 38.00]

T (°K)	C _p (cal/mole °K)	H ₂ -H ₀ (kcal/mole)	H _f (kcal/mole)	S _f (cal/mole °K)	ΔH ^o RT	δ(-ΔH ^o /RT) = -δT(a/T+b)		log K'	δ log K = -δT(c/T+d)	
						a	b		c	d
0		0	60.9562							
288.16	7.5183	2.1137	63.0699	48.5590	61.7763			20.8831		
300	7.5262	2.1276	63.0638	48.6053	61.4076			20.7035		
400	7.9077	2.9001	68.8563	50.8261	46.4428			14.0101		
500	8.1822	3.7055	64.6677	52.8211	37.4145			9.9626		
900	8.3704	4.5837	65.4899	54.1806	31.8646			7.2467		
700	8.5004	5.3776	66.3338	55.4313	27.0238			5.2959		
800	8.5924	6.2925	67.1837	56.6727	23.7560			3.8236		
900	8.6593	7.0933	68.0515	57.8889	21.2083			2.6708		
1000	8.7092	7.6438	68.9205	58.9942	19.1610	1825	0.01791	1.7540	317	0.01517
1100	8.7472	8.0371	69.7933	59.9360	17.4840	1663	0.01427	0.9961	745	0.01297
1200	8.7768	9.1733	70.6695	60.0884	16.0839	1528	0.1142	0.3623	684	0.01205
1300	8.8002	10.6921	71.5483	60.8019	14.8971	1413	0.0831	-1.1759	632	0.01076
1400	8.8190	11.4731	72.4298	61.4547	13.8785	1315	0.0733	-1.6338	589	0.00983
1500	8.8326	12.3557	73.3119	62.0636	12.9945	1229	0.0618	-1.0413	551	0.00883
1600	8.8471	13.2397	74.1959	62.6341	12.2302	1154	0.0518	-1.2945	518	0.00799
1700	8.8577	14.1249	75.0811	63.1708	11.6362	1087	0.0431	-1.7072	488	0.00759
1800	8.8666	15.0111	75.9673	63.6774	10.9277	1028	0.0375	-1.8859	462	0.00694
1900	8.8742	15.8982	76.8544	64.1570	10.3829	975	0.0330	-2.2300	438	0.00630
2000	8.8807	16.7859	77.7421	64.6123	9.8921	927	0.0287	-2.4618	417	0.00583
2100	8.8863	17.6742	78.6304	65.0457	9.4478	884	0.0238	-2.6667	398	0.00579
2200	8.8912	18.5631	79.5193	65.4592	9.0436	844	0.0224	-2.8334	381	0.00535
2300	8.8955	19.4525	80.4087	65.8546	8.6744	806	0.0193	-3.0744	365	0.00512
2400	8.8993	20.3422	81.2984	66.2332	8.3388	775	0.0170	-3.1818	350	0.00500
2500	8.9026	21.2323	82.1885	66.5966	8.0241	744	0.0165	-3.3266	336	0.00497
2600	8.9056	22.1227	83.0789	66.9458	7.7363	716	0.0152	-3.4608	324	0.00480
2700	8.9082	23.0134	83.9696	67.2819	7.4696	690	0.0117	-3.5854	313	0.00431
2800	8.9106	23.1043	84.0605	67.6060	7.2220	666	0.0104	-3.7015	302	0.00416
2900	8.9127	24.7955	85.7517	67.9187	6.9913	643	0.0107	-3.8098	292	0.00397
3000	8.9146	25.6589	86.6431	68.2209	6.7759	622	0.0085	-3.9111	283	0.00371
3100	8.9164	26.5784	87.5346	68.5132	6.5744	602	0.0088	-4.0061	275	0.00340
3200	8.9180	27.4701	88.4263	68.7963	6.3854	584	0.0063	-4.0955	268	0.00349
3300	8.9194	28.3620	89.3182	69.0708	6.2078	566	0.0063	-4.1796	259	0.00332
3400	8.9209	29.2540	90.2102	69.3370	6.0407	550	0.0056	-4.2590	251	0.00339
3500	8.9220	30.1462	91.1024	69.5956	5.8830	534	0.0057	-4.3341	244	0.00322
3600	8.9231	31.0384	91.9946	69.8470	5.7341	520	0.0046	-4.4051	238	0.00308
3700	8.9241	31.9308	92.8870	70.0915	5.5931	506	0.0034	-4.4725	232	0.00295
3800	8.9250	32.8232	93.7794	70.3295	5.4596	492	0.0055	-4.5365	226	0.00295
3900	8.9259	33.7158	94.6720	70.5614	5.3329	480	0.0040	-4.5974	221	0.00275
4000	8.9267	34.6084	95.5646	70.7873	5.2125	468	0.0035	-4.6554	215	0.00276
4100	8.9274	35.5011	96.4573	71.0078	5.0980	457	0.0039	-4.7106	210	0.00280
4200	8.9281	36.3936	97.3501	71.2229	4.9888	446	0.0028	-4.7634	206	0.00289
4300	8.9288	37.2867	98.2429	71.4330	4.8848	436	0.0022	-4.8139	201	0.00262
4400	8.9294	38.1796	99.1358	71.6383	4.7855	426	0.0023	-4.8622	196	0.00264
4500	8.9300	39.0726	100.0288	71.8390	4.6906	417	0.0025	-4.9084	192	0.00256
4600	8.9305	39.9656	100.9218	72.0352	4.6007	407	0.0030	-4.9527	188	0.00280
4700	8.9310	40.8587	101.8149	72.2273	4.5128	399	0.0028	-4.9953	184	0.00247
4800	8.9315	41.7518	102.7080	72.4153	4.4264	391	0.0010	-5.0361	181	0.00246
4900	8.9319	42.6450	103.6012	72.5995	4.3405	383	0.0020	-5.0755	177	0.00240
5000	8.9323	43.5382	104.4944	72.7800	4.2727	375	0.0027	-5.1133	174	0.00228
5100	8.9327	44.4315	105.3877	72.9568	4.1989	368	0.0013	-5.1497	171	0.00222
5200	8.9331	45.3248	106.2810	73.1308	4.1280	361	0.0019	-5.1848	168	0.00220
5300	8.9334	46.2181	107.1743	73.3005	4.0597	354	0.0014	-5.2187	165	0.00214
5400	8.9337	47.1114	108.0676	73.4674	3.9940	348	0.0013	-5.2514	161	0.00223
5500	8.9340	48.0048	108.9610	73.6314	3.9306	341	0.0021	-5.2829	159	0.00221
5600	8.9343	48.8982	109.8544	73.7924	3.8695	335	0.0023	-5.3135	156	0.00213
5700	8.9346	49.7917	110.7479	73.9505	3.8105	329	0.0018	-5.3430	153	0.00222
5800	8.9349	50.6852	111.6414	74.1059	3.7536	324	0.0008	-5.3710	150	0.00218
5900	8.9351	51.5787	112.5349	74.2588	3.6988	318	0.0020	-5.3982	148	0.00213
6000	8.9353	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 ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)	$H_f - H_g$ ($\frac{\text{kcal}}{\text{mole}}$)	H_f ($\frac{\text{kcal}}{\text{mole}}$)	S_f ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)
0	—	0	85.3285	—
298.16	4.9680	1.4812	86.8097	27.3927
300	4.9680	1.4904	86.8189	27.4232
400	4.9680	1.9672	87.3167	28.8624
500	4.9680	2.4840	87.8125	29.9610
600	4.9680	2.9808	88.3083	30.8667
700	4.9680	3.4776	88.8051	31.6328
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	92.7806	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	36.5982
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	40.1668
4000	4.9680	19.8720	105.2006	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	42.3069

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TABLE XXX—THERMODYNAMIC PROPERTIES OF H₂ (GAS)

[Molecular weight, 2.016]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)	H ₂ -H ₂ ($\frac{\text{kcal}}{\text{mole}}$)	H _f ($\frac{\text{kcal}}{\text{mole}}$)	S _f ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)	$\frac{\Delta H^\circ}{RT}$	$s\left(\frac{\Delta H^\circ}{RT}\right) = \frac{-\Delta T}{100}\left(\frac{a}{T}+b\right)$		log K	$\Delta \log K = \frac{-\Delta T}{100}\left(\frac{c}{T}+d\right)$	
						a	b		c	d
0	-----	0	67.4169	-----	-----	-----	-----	-----	-----	-----
298.16	6.892	2.0298	69.4407	31.211	178.8267	-----	-----	71.2008	-----	-----
300	6.895	2.0365	69.4834	31.253	174.7610	-----	-----	70.7414	-----	-----
400	6.974	2.7310	70.1479	33.280	131.4465	-----	-----	61.7421	-----	-----
500	6.993	3.4295	70.8464	34.809	105.4544	-----	-----	40.3059	-----	-----
600	7.008	4.1286	71.5455	36.084	88.1261	-----	-----	32.0659	-----	-----
700	7.035	4.8315	72.2484	37.187	78.7454	-----	-----	27.1921	-----	-----
800	7.078	5.5374	72.9543	38.108	68.4582	-----	-----	23.0744	-----	-----
900	7.139	6.2480	73.6649	38.946	58.2322	-----	-----	19.8636	-----	-----
1000	7.219	6.9658	74.3827	39.7040	53.4478	6186	0.02306	17.2853	2291	0.03007
1100	7.310	7.6923	75.1092	40.3963	48.7111	4712	0.02453	15.1756	2087	0.02583
1200	7.407	8.4281	75.8450	41.0865	44.7899	4318	0.02536	13.4306	1916	0.02315
1300	7.509	9.1789	76.5908	41.6384	41.4228	3985	0.02637	11.9138	1772	0.02029
1400	7.615	9.9301	77.3470	42.1938	38.5400	3700	0.02653	10.6278	1643	0.01833
1500	7.7202	10.6989	78.1138	42.7227	36.0468	3454	0.02605	9.5103	1541	0.01628
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	0.02400	7.6652	1364	0.01332
1800	8.0185	13.0594	80.4763	44.1571	30.2121	2884	0.02281	6.8941	1291	0.01173
1900	8.1093	13.8648	81.2817	44.5931	28.6718	2734	0.02170	6.2029	1225	0.01060
2000	8.1949	14.6800	82.0969	45.0112	27.2629	2600	0.02031	5.5798	1169	0.00946
2100	8.2762	15.5036	82.9208	45.4130	25.9245	2478	0.01954	5.0151	1112	0.00866
2200	8.3537	16.3351	83.7620	45.7998	24.6788	2367	0.01867	4.5010	1063	0.00793
2300	8.4274	17.1741	84.6210	46.1728	23.5308	2267	0.01752	4.0309	1018	0.00733
2400	8.4977	18.0204	85.4973	46.5329	22.4857	2174	0.01690	3.5904	978	0.00680
2500	8.5647	18.8735	86.3904	46.8812	21.5222	2089	0.01604	3.2018	940	0.00656
2600	8.6288	19.7331	87.1500	47.2183	21.1627	2011	0.01519	2.8344	905	0.00641
2700	8.6896	20.5991	88.0180	47.5451	20.4027	1938	0.01408	2.4938	873	0.00631
2800	8.7479	21.4709	88.8978	47.8622	19.6959	1870	0.01417	2.1772	843	0.00641
2900	8.8042	22.3485	89.7654	48.1702	19.0369	1807	0.01377	1.8821	816	0.00673
3000	8.8587	23.2317	90.6486	48.4696	18.4208	1748	0.01323	1.6064	789	0.00688
3100	8.9118	24.1202	91.5371	48.7609	17.8437	1693	0.01294	1.3482	764	0.00655
3200	8.9636	25.0140	92.4309	49.0447	17.3017	1640	0.01283	1.1089	741	0.00626
3300	9.0143	25.9129	93.3298	49.3214	16.7919	1591	0.01298	.8781	719	0.00613
3400	9.0639	26.8168	94.2337	49.5911	16.3113	1546	0.01219	.6635	699	0.00679
3500	9.1125	27.7250	95.1425	49.8548	15.8574	1502	0.01208	.4610	680	0.00641
3600	9.1602	28.6392	96.0561	50.1119	15.4281	1461	0.01184	0.2697	662	0.00628
3700	9.2070	29.5576	96.9745	50.3635	15.0214	1423	0.01153	.0885	644	0.00623
3800	9.2523	30.4806	97.8975	50.6097	14.6354	1386	0.01132	-.0832	628	0.00619
3900	9.2979	31.4081	98.8260	50.8505	14.2687	1351	0.01125	-.2462	613	0.00675
4000	9.3421	32.3401	99.7670	51.0866	13.9197	1318	0.01104	-.4012	598	0.00665
4100	9.3856	33.2765	100.6934	51.3178	13.5872	1287	0.01067	-.5487	584	0.00646
4200	9.4283	34.2172	101.6341	51.5446	13.2701	1257	0.01057	-.6892	571	0.00631
4300	9.4704	34.1631	102.5790	51.7668	12.9672	1229	0.01038	-.8233	558	0.00618
4400	9.5118	35.1113	103.5282	51.9850	12.6775	1201	0.01031	-.9513	546	0.00697
4500	9.5526	37.0645	104.4814	52.1992	12.4003	1175	0.01017	-1.0736	535	0.00680
4600	9.5928	38.0217	105.4386	52.4096	12.1347	1150	0.01002	-1.1907	524	0.00671
4700	9.6324	38.9830	106.3999	52.6164	11.8800	1127	0.00971	-1.3029	514	0.00642
4800	9.6714	39.9482	107.3651	52.8196	11.6355	1104	0.00969	-1.4104	503	0.00645
4900	9.7099	40.9173	108.3342	53.0194	11.4005	1082	0.00950	-1.5135	494	0.00630
5000	9.7479	41.8901	109.3070	53.2159	11.1746	1061	0.00936	-1.6126	484	0.00620
5100	9.7853	42.8668	110.2837	53.4093	10.9572	1041	0.00931	-1.7077	475	0.00615
5200	9.8222	43.8472	111.2641	53.5997	10.7477	1021	0.00916	-1.7992	466	0.00618
5300	9.8586	44.8312	112.2481	53.7871	10.5459	1003	0.00906	-1.8873	458	0.00601
5400	9.8945	45.8189	113.2358	53.9717	10.3511	985	0.00891	-1.9721	450	0.00602
5500	9.9299	46.8101	114.2270	54.1536	10.1631	967	0.00882	-2.0539	442	0.00613
5600	9.9649	47.8049	115.2217	54.3328	9.9816	951	0.00870	-2.1327	434	0.00614
5700	9.9994	48.8031	116.2200	54.5095	9.8060	935	0.00867	-2.2087	427	0.00612
5800	10.0334	49.8047	117.2216	54.6837	9.6363	919	0.00854	-2.2822	420	0.00629
5900	10.0670	50.8097	118.2266	54.8556	9.4720	904	0.00843	-2.3531	413	0.00633
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 ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H _f - H ₀ ($\frac{\text{kcal}}{\text{mole}}$)	H _f ($\frac{\text{kcal}}{\text{mole}}$)	S _f ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^\circ}{RT}$	$a \left(\frac{-\Delta H^\circ}{RT} - \frac{-5T}{100} \left(\frac{c}{T} + b \right) \right)$		log K	$s \log K = \frac{-5T}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0	-----	0	15.5828	-----	-----	-----	-----	-----	-----	-----
298.16	6.96	2.0648	17.6574	44.617	174.1180	-----	-----	70.7696	-----	-----
300	6.96	2.0778	17.6704	44.661	172.0598	-----	-----	70.2960	-----	-----
400	6.97	2.7740	18.3666	46.656	130.2113	-----	-----	51.4775	-----	-----
500	7.00	3.4730	19.0666	48.224	104.6100	-----	-----	40.1522	-----	-----
600	7.07	4.1766	19.7692	49.506	87.8747	-----	-----	32.5736	-----	-----
700	7.17	4.8881	20.4807	50.603	73.1291	-----	-----	27.1493	-----	-----
800	7.29	5.6112	21.2033	51.568	65.9366	-----	-----	22.0623	-----	-----
900	7.42	6.3468	21.9394	52.434	58.7762	-----	-----	19.8761	-----	-----
1000	7.554	7.0930	22.6876	53.2220	53.0404	5124	0.04262	17.8201	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	.03860	13.4719	1903	.02145
1300	7.938	9.4205	25.0131	55.2536	41.0854	3962	.03754	11.9868	1780	.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	33.6792	3227	0.02197	8.6314	1437	0.01331
1700	8.292	12.6727	28.2633	57.4325	31.9590	3040	.02031	7.7728	1355	.01172
1800	8.358	13.5062	29.0978	57.9084	29.9498	2871	.02045	7.0688	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	58.7968	27.0381	2590	.01717	5.7056	1167	.00855
2100	8.545	16.0417	31.6343	59.2114	25.7876	2471	0.01602	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	35.9648	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	19.5034	1868	.00846	2.3347	834	.00471
2900	8.866	23.0155	38.6081	62.0223	18.8568	1805	.00783	2.0424	806	.00443
3000	8.895	23.9026	39.4952	62.3231	18.2463	1745	.00780	1.7693	780	.00409
3100	8.912	24.7925	40.3851	62.6148	17.6736	1691	0.00706	1.5136	756	0.00376
3200	8.937	25.6849	41.2775	62.8982	17.1401	1639	.00683	1.2736	733	.00368
3300	8.961	26.5788	42.1724	63.1736	16.6366	1591	.00626	1.0479	711	.00345
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	.00678	.6346	671	.00321
3600	9.024	29.2773	44.8704	63.9560	15.2919	1462	0.00527	0.4450	654	0.00284
3700	9.043	30.1811	45.7737	64.2036	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	32.9026	48.4952	64.9108	13.8089	1318	.00474	-.2202	590	.00250
4100	9.115	33.8122	49.4058	65.1356	13.4827	1287	0.00437	-.3866	576	0.00226
4200	9.131	34.7265	50.3181	65.3554	13.1719	1256	.00451	-.5600	563	.00217
4300	9.147	35.6394	51.2320	65.5705	12.8763	1228	.00421	-.7391	551	.00197
4400	9.162	36.5549	52.1476	65.7810	12.5920	1202	.00379	-.9263	538	.00194
4500	9.176	37.4718	53.0644	65.9870	12.3211	1174	.00408	-.1178	527	.00183
4600	9.191	38.3901	53.9827	66.1888	12.0618	1150	0.00372	-.10042	516	0.00171
4700	9.205	39.3099	54.9025	66.3867	11.8134	1127	.00341	-.11167	505	.00169
4800	9.218	40.2311	55.8237	66.5806	11.5732	1102	.00390	-.12226	495	.00168
4900	9.232	41.1536	56.7462	66.7708	11.3465	1081	.00340	-.13252	485	.00160
5000	9.245	42.0774	57.6700	66.9574	11.1269	1060	.00336	-.14288	476	.00147
5100	9.257	43.0025	58.5951	67.1406	10.9157	1038	0.00348	-.15186	467	0.00139
5200	9.270	43.9289	59.5215	67.3205	10.7126	1020	.00325	-.16098	458	.00138
5300	9.282	44.8565	60.4491	67.4972	10.5169	1001	.00313	-.16976	449	.00145
5400	9.294	45.7863	61.3779	67.6708	10.3284	982	.00325	-.17822	441	.00142
5500	9.306	46.7163	62.3079	67.8415	10.1466	964	.00316	-.18638	433	.00138
5600	9.318	47.6465	63.2391	68.0093	9.9713	947	0.00326	-.19425	426	0.00126
5700	9.330	48.5789	64.1715	68.1743	9.8019	930	.00326	-.20185	419	.00116
5800	9.342	49.5125	65.1051	68.3367	9.6383	914	.00328	-.20919	412	.00117
5900	9.354	50.4473	66.0399	68.4966	9.4801	900	.00300	-.21629	405	.00110
6000	9.365	51.3832	66.9758	68.6538	9.3271	-----	-----	-.22315	-----	-----

REPORT 1037—NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TABLE XXXII—THERMODYNAMIC PROPERTIES OF HF (GAS)

[Molecular weight, 20.008]

T (°K)	C_p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$H_f - H_g$ ($\frac{\text{kcal}}{\text{mole}}$)	H_f ($\frac{\text{kcal}}{\text{mole}}$)	S_f ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^\circ}{RT}$	$s \left(\frac{-\Delta H^\circ}{RT} \right) - \frac{-sT}{100} \left(\frac{a}{T} + b \right)$		log K	$s \log K = \frac{-sT}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0		0	0	0						
298.16	6.9615	2.0553	2.0553	41.5114	227.1579			98.4533		
300	6.9615	2.0681	2.0681	41.5542	225.7754			92.8472		
400	6.9632	2.7845	2.7845	43.5575	169.7599			68.3058		
500	6.9715	3.4813	3.4813	45.1124	136.1421			53.5438		
600	6.9858	4.1592	4.1592	46.2845	113.7233			43.6784		
700	7.0150	4.8522	4.8522	47.4639	97.7043			36.6149		
800	7.0627	5.5631	5.5631	48.4098	85.6849			31.3051		
900	7.1290	6.2737	6.2737	49.2396	76.3916			27.1690		
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	50.6856	62.7128	6103	0.02817	21.1269	2694	0.02690
1200	7.4035	8.4506	8.4506	51.3284	57.5038	5594	0.02852	18.6550	2473	0.02359
1300	7.5059	9.1962	9.1962	51.9231	53.2672	5184	0.02823	16.9291	2287	0.02033
1400	7.6084	9.9520	9.9520	52.4811	49.5504	4797	0.02700	15.2752	2126	0.01847
1500	7.7084	10.7178	10.7178	53.0114	46.3254	4479	0.02573	13.8394	1967	0.01653
1600	7.8048	11.4935	11.4935	53.5120	43.5003	4201	0.02432	12.5810	1806	0.01455
1700	7.8967	12.2785	12.2785	53.9879	41.0046	3956	0.02332	11.4688	1738	0.01333
1800	7.9836	13.0726	13.0726	54.4417	38.7825	3739	0.02161	10.4758	1662	0.01236
1900	8.0657	13.8750	13.8750	54.8756	36.7940	3545	0.02030	9.5917	1577	0.01100
2000	8.1427	14.6854	14.6854	55.2912	35.0012	3370	0.01904	8.7922	1500	0.01011
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	0.01655	7.4066	1367	0.00835
2300	8.3464	17.1597	17.1597	56.4436	30.5486	2938	0.01543	6.8050	1309	0.00758
2400	8.4061	17.9973	17.9973	56.8001	29.3090	2818	0.01450	6.2538	1256	0.00710
2500	8.4623	18.8407	18.8407	57.1444	28.1673	2707	0.01385	5.7433	1206	0.00665
2600	8.5152	19.6896	19.6896	57.4773	27.1123	2605	0.01289	5.2726	1161	0.00630
2700	8.5650	20.5438	20.5438	57.7996	26.1346	2510	0.01247	4.8363	1119	0.00596
2800	8.6124	21.4025	21.4025	58.1119	25.2257	2423	0.01148	4.4307	1080	0.00569
2900	8.6572	22.2660	22.2660	58.4149	24.3787	2341	0.01087	4.0528	1044	0.00510
3000	8.7000	23.1338	23.1338	58.7091	23.5675	2264	0.01058	3.6997	1010	0.00479
3100	8.7408	24.0059	24.0059	58.9951	22.8466	2198	0.00999	3.3691	979	0.00426
3200	8.7797	24.8819	24.8819	59.2732	22.1813	2126	0.00946	3.0589	949	0.00402
3300	8.8169	25.7617	25.7617	59.5439	21.5698	2063	0.00903	2.7673	921	0.00382
3400	8.8527	26.6452	26.6452	59.8077	20.9818	2003	0.00861	2.4926	895	0.00349
3500	8.8872	27.5322	27.5322	60.0648	20.3007	1947	0.00847	2.2334	870	0.00333
3600	8.9205	28.4226	28.4226	60.3156	19.7514	1894	0.00821	1.9884	847	0.00303
3700	8.9528	29.3162	29.3162	60.5605	19.2313	1843	0.00820	1.7564	824	0.00296
3800	8.9842	30.2131	30.2131	60.7996	18.7381	1795	0.00794	1.5366	804	0.00285
3900	9.0151	31.1130	31.1130	61.0334	18.2699	1750	0.00780	1.3278	784	0.00240
4000	9.0453	32.0161	32.0161	61.2620	17.8246	1707	0.00756	1.1294	765	0.00231
4100	9.0750	32.9221	32.9221	61.4858	17.4007	1666	0.00733	0.9405	746	0.00226
4200	9.1043	33.8310	33.8310	61.7048	16.9967	1626	0.00756	0.7606	730	0.00203
4300	9.1336	34.7429	34.7429	61.9194	16.6111	1588	0.00759	0.5888	713	0.00195
4400	9.1631	35.6578	35.6578	62.1297	16.2426	1551	0.00773	0.4248	697	0.00191
4500	9.1936	36.5756	36.5756	62.3359	15.8902	1513	0.00849	0.2680	682	0.00174
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	0.00915	-0.0258	654	0.00155
4800	9.2978	39.3491	39.3491	62.9326	14.9190	1416	0.00902	-0.1636	641	0.00138
4900	9.3335	40.2807	40.2807	63.1246	14.6210	1387	0.00910	-0.2948	629	0.00130
5000	9.3690	41.2158	41.2158	63.3138	14.3345	1360	0.00898	-0.4229	616	0.00132
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	0.00872	-0.6624	592	0.00130
5300	9.4728	44.0422	44.0422	63.8625	13.5379	1285	0.00844	-0.7754	582	0.00112
5400	9.5061	44.9911	44.9911	64.0399	13.2915	1262	0.00843	-0.8843	571	0.00118
5500	9.5391	45.9434	45.9434	64.2146	13.0536	1240	0.00817	-0.9893	561	0.00112
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	0.00795	-1.1883	541	0.00102
5800	9.6358	48.8197	48.8197	64.7238	12.3876	1177	0.00801	-1.2826	532	0.00103
5900	9.6673	49.7849	49.7849	64.8888	12.1801	1158	0.00780	-1.3738	524	0.00097
6000	9.6986	50.7531	50.7531	65.0515	11.9793			-1.4621		

TABLE XXXIII—THERMODYNAMIC PROPERTIES OF H₂O (GAS)

[Molecular weight, 18.016]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)	H _f - H _g ($\frac{\text{kcal}}{\text{mole}}$)	H _f ($\frac{\text{kcal}}{\text{mole}}$)	S _f ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)	$\frac{\Delta H^\circ}{RT}$	$\delta \left(\frac{-\Delta H^\circ}{RT} \right) = -\frac{\delta T}{100} \left(\frac{a}{T} + b \right)$		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	2.3877	13.6988	45.106	373.2200	-----	-----	151.6648	-----	-----
300	8.026	2.3820	13.7131	45.154	370.9541	-----	-----	160.5708	-----	-----
400	8.185	3.1940	14.5251	47.490	279.0956	-----	-----	110.2872	-----	-----
500	8.415	4.0255	15.3666	49.344	228.9534	-----	-----	85.9609	-----	-----
600	8.677	4.8822	16.2183	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	126.7485	-----	-----	42.6361	-----	-----
1000	9.851	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	103.2487	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	87.7966	8.486	.06187	25.6655	3788	.03457
1400	10.909	12.7691	24.1002	59.1084	81.6758	7.886	.05906	22.9395	3505	.03013
1500	11.134	13.8712	25.2023	59.8687	76.3615	7.366	.056315	20.6727	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	67.5989	6.514	.04401	16.6662	2896	.02200
1800	11.706	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	20.8906	32.2117	63.7900	55.0087	5.299	0.02966	11.0695	2359	0.01423
2200	12.256	22.1033	33.4314	64.3574	52.4704	5.064	.02686	9.9720	2255	.01277
2300	12.364	23.3313	34.6824	64.9045	50.3418	4.849	.02468	8.9798	2160	.01150
2400	12.463	24.5727	35.9638	65.4328	48.2987	4.658	.02220	8.0688	2072	.01040
2500	12.554	25.8235	37.1546	65.9434	46.4133	4.471	.02049	7.2259	1991	.00963
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	39.6319	66.9159	43.0605	4.149	.01691	5.7343	1846	.00896
2800	12.786	29.6258	40.9589	67.3796	41.5618	4.005	.01547	5.0661	1781	.00856
2900	12.852	30.9077	42.2368	67.8294	40.1833	3.871	.01407	4.4434	1721	.00803
3000	12.913	32.1960	43.5271	68.2681	38.9609	3.747	.01239	3.8617	1666	.00728
3100	12.968	33.4900	44.8211	68.6904	37.6368	3.630	0.01113	3.3170	1613	0.00694
3200	13.018	34.7838	46.1204	69.1029	36.4943	3.520	.00993	2.8060	1564	.00656
3300	13.064	36.0834	47.4245	69.5042	35.4177	3.417	.00880	2.3255	1517	.00612
3400	13.107	37.4020	48.7331	69.8940	34.4038	3.320	.00783	1.8729	1473	.00562
3500	13.147	38.7147	50.0458	70.2734	33.4473	3.228	.00703	1.4458	1431	.00510
3600	13.184	40.0312	51.3623	70.6463	32.5436	3.142	0.00601	1.0422	1392	0.00488
3700	13.218	41.3613	52.6824	71.0060	31.6884	3.059	.00550	.6601	1355	.00472
3800	13.250	42.6747	54.0058	71.3609	30.8779	2.981	.00484	.2978	1320	.00454
3900	13.280	44.0012	55.3323	71.7054	30.1087	2.907	.00425	-.0462	1287	.00425
4000	13.308	45.3306	56.6617	72.0420	29.3777	2.836	.00379	-.3732	1255	.00380
4100	13.334	46.6627	57.9938	72.3710	28.6822	2.769	0.00321	-.6845	1266	0.00480
4200	13.358	47.9973	59.3284	72.6926	28.0197	2.705	.00283	-.9812	1198	.00450
4300	13.381	49.3343	60.6634	73.0071	27.3878	2.643	.00252	-1.2643	1170	.00449
4400	13.403	50.6736	62.0046	73.3150	26.7845	2.584	.00228	-1.5347	1144	.00438
4500	13.424	52.0143	63.3469	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	54.7066	66.0347	74.2011	25.1261	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	-2.7233	1030	.00370
5000	13.521	58.7414	70.0826	75.0359	23.6698	2.276	.00158	-2.9336	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	61.4694	72.7905	75.5669	22.7907	2.189	.00168	-3.3291	973	.00322
5300	13.577	62.8162	74.1473	75.8264	22.3760	2.148	.00172	-3.5159	955	.00315
5400	13.596	64.1748	75.5059	76.0794	21.9763	2.108	.00163	-3.6959	938	.00305
5500	13.614	65.5353	76.8664	76.3290	21.5916	2.070	.00166	-3.8695	921	.00294
5600	13.633	66.8977	78.2288	76.5746	21.2203	2.033	0.00163	-4.0370	905	0.00283
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	.00169	-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	1.898	-----	-4.6522	-----	-----

TABLE XXXIV—THERMODYNAMIC PROPERTIES OF
 e^- (ELECTRON GAS)[Atomic weight, 5.4847×10^{-4}]

T (°K)	C_p^0 ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$H_T - H_0^0$ ($\frac{\text{kcal}}{\text{mole}}$)	H_T^0 ($\frac{\text{kcal}}{\text{mole}}$)	S_T^0 ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)
0	-----	0	60.0000	-----
298.16	4.9680	1.4912	61.4912	4.9682
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	7.8568
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	10.4708
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	13.6382
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	18.4722
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	19.9016

TABLE XXXV—THERMODYNAMIC PROPERTIES OF F₂ (GAS)

[Atomic weight, 19.00]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H ₂ - H ₂ ⁰ ($\frac{\text{kcal}}{\text{mole}}$)	H ₂ ⁰ ($\frac{\text{kcal}}{\text{mole}}$)	S ₂ ⁰ ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^0}{RT}$	$\ln \left(\frac{\Delta H^0}{RT} \right) - \frac{1}{100} \left(\frac{a}{T} + b \right)$		log K	$\ln \log K - \frac{1}{100} \left(\frac{c}{T} + d \right)$	
						α	β		c	d
0		0	11.9781	34.7682	165.1819			69.9505		
298.16	4.9680	1.4512	13.4593	34.7682	165.1819			69.9505		
300	4.9680	1.4904	13.4635	34.7688	164.1656			69.9106		
400	4.9680	1.9872	13.9653	35.2280	123.8037			51.6419		
500	4.9680	2.4840	14.4621	37.8366	99.5784			40.8614		
600	4.9680	2.9808	14.9589	38.2423	83.4222			33.6357		
700	4.9680	3.4776	15.4567	39.0081	71.8780			28.4472		
800	4.9680	3.9744	15.9525	39.6715	63.2172			24.5365		
900	4.9680	4.4712	16.4483	40.2688	56.4793			21.4776		
1000	4.9680	4.9679	16.9460	40.7891	51.0877	4849	0.00402	19.0187	2164	0.05468
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	0.00297	15.8035	1812	0.04605
1300	4.9680	6.4583	18.4364	42.0835	39.8358	3732	0.00219	13.8698	1677	0.04294
1400	4.9680	6.9551	18.9322	42.4517	37.2179	3466	0.00193	12.6234	1561	0.03953
1500	4.9680	7.4519	19.4300	42.7944	34.9053	3225	0.00172	11.5432	1461	0.03648
1600	4.9680	7.9487	19.9288	43.1150	32.8817	3034	0.00110	10.5986	1373	0.03435
1700	4.9680	8.4455	20.4236	43.4182	31.0959	2855	0.00129	9.7316	1296	0.03210
1800	4.9680	8.9423	20.9204	43.7002	29.5085	2697	0.00193	8.9995	1227	0.03021
1900	4.9680	9.4391	21.4172	43.9688	28.0880	2555	0.00110	8.3235	1165	0.02890
2000	4.9680	9.9359	21.9140	44.2236	26.8094	2428	0.00061	7.7121	1110	0.02713
2100	4.9680	10.4327	22.4108	44.4680	25.6326	2312	0.00079	7.1564	1059	0.02614
2200	4.9680	10.9295	22.9076	44.6971	24.6009	2207	0.00073	6.6489	1014	0.02473
2300	4.9680	11.4263	23.4044	44.9179	23.6406	2112	0.00040	6.1833	972	0.02380
2400	4.9680	11.9231	23.9012	45.1294	22.7802	2024	0.00080	5.7546	924	0.02270
2500	4.9680	12.4199	24.3980	45.3322	21.9503	1943	0.00039	5.3582	890	0.02173
2600	4.9680	12.9167	24.8948	45.5270	21.2028	1868	0.00043	4.9907	866	0.02106
2700	4.9680	13.4135	25.3916	45.7145	20.5103	1799	0.00040	4.6489	836	0.02023
2800	4.9680	13.9103	25.8884	45.8952	19.8674	1735	0.00032	4.3301	806	0.01938
2900	4.9680	14.4071	26.3852	46.0695	19.2688	1675	0.00037	4.0319	782	0.01893
3000	4.9680	14.9039	26.8820	46.2379	18.7101	1619	0.00044	3.7523	753	0.01818
3100	4.9680	15.4007	27.3788	46.4008	18.1874	1567	0.00031	3.4996	735	0.01761
3200	4.9680	15.8975	27.8756	46.5586	17.6974	1518	0.00030	3.2423	714	0.01704
3300	4.9680	16.3943	28.3724	46.7114	17.2371	1472	0.00036	3.0089	694	0.01668
3400	4.9680	16.8911	28.8692	46.8598	16.8038	1429	0.00021	2.7882	675	0.01614
3500	4.9680	17.3879	29.3660	47.0038	16.3963	1388	0.00024	2.5792	658	0.01542
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	1318	0.00027	2.1927	625	0.01473
3800	4.9680	18.8783	30.8564	47.4123	15.2987	1279	0.00006	2.0185	610	0.01429
3900	4.9680	19.3751	31.3532	47.5414	14.9707	1246	0.00010	1.8428	595	0.01415
4000	4.9680	19.8719	31.8500	47.6672	14.6591	1215	0.00016	1.6799	582	0.01365
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	0.00013	1.3756	557	0.01297
4300	4.9680	21.3623	33.3404	48.0264	13.8110	1130	0.00018	1.2330	545	0.01274
4400	4.9680	21.8591	33.8372	48.1406	13.5540	1104	0.00017	1.0964	534	0.01243
4500	4.9680	22.3559	34.3340	48.2523	13.3085	1080	0.00012	0.9653	524	0.01199
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	0.00008	0.7183	504	0.01150
4800	4.9680	23.8463	35.8244	48.5729	12.6332	1018	0.00007	0.6018	494	0.01138
4900	4.9680	24.3431	36.3212	48.6754	12.4264	992	0.00000	0.4896	485	0.01110
5000	4.9680	24.8399	36.8180	48.7767	12.2280	972	0.00011	0.3815	477	0.01087
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	0.00017	0.1764	460	0.01051
5300	4.9680	26.3303	38.3084	49.0652	11.6775	917	0.00009	0.0791	453	0.01031
5400	4.9680	26.8271	38.8052	49.1581	11.5076	900	0.00016	-0.0151	445	0.01009
5500	4.9680	27.3239	39.3020	49.2492	11.3438	883	0.00012	-0.1061	439	0.00981
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	0.00003	-0.2797	425	0.00942
5800	4.9680	28.8143	40.7924	49.5131	10.8865	838	0.00007	-0.3624	419	0.00928
5900	4.9680	29.3111	41.2892	49.5980	10.7444	824	0.00007	-0.4427	413	0.00917
6000	4.9680	29.8079	41.7860	49.6815	10.6070			-0.5207		

TABLE XXXVI—THERMODYNAMIC PROPERTIES OF Li+ (GAS)

[Atomic weight, 6.940]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H ₂ -H ₃ ($\frac{\text{kcal}}{\text{mole}}$)	H _f ($\frac{\text{kcal}}{\text{mole}}$)	S _f ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^\circ}{RT}$	$s \left(-\frac{\Delta H^\circ}{RT} - \frac{-sT}{100} \left(\frac{c}{T} + d \right) \right)$		log K	$s \log K - \frac{-sT}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0		0	230.7290							
298.16	4.9680	1.4813	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	-158.2923			-67.6371		
500	4.9680	2.4829	233.2129	34.3345	-127.1337			-53.8829		
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	-0.03580
1100	4.9680	5.4647	236.1937	38.2515	-59.1518	-5695	-0.00017	-23.4826	-2515	-0.04897
1200	4.9680	5.9615	236.6905	38.6838	-54.4308	-5193	-0.00008	-21.3378	-2310	-0.04488
1300	4.9680	6.4583	237.1873	39.0814	-50.4361	-4798	-0.00043	-19.5160	-2136	-0.04179
1400	4.9680	6.9551	237.6841	39.4496	-47.0121	-4451	-0.00017	-17.9485	-1987	-0.03893
1500	4.9680	7.4519	238.1809	39.7924	-44.0446	-4154	-0.00035	-16.5849	-1858	-0.03655
1600	4.9680	7.9487	238.6777	40.1130	-41.4480	-3884	-0.00051	-15.3871	-1745	-0.03433
1700	4.9680	8.4455	239.1745	40.4142	-39.1569	-3644	-0.00104	-14.3263	-1646	-0.03206
1800	4.9680	8.9423	239.6713	40.6981	-37.1203	-3420	-0.00125	-13.3798	-1558	-0.03000
1900	4.9680	9.4391	240.1681	40.9668	-35.2980	-3217	-0.00180	-12.5298	-1479	-0.02840
2000	4.9680	9.9359	240.6649	41.2216	-33.6577	-3112	-0.00220	-11.7619	-1408	-0.02682
2100	4.9680	10.4327	241.1617	41.4640	-32.1736	-2993	-0.00258	-11.0646	-1343	-0.02585
2200	4.9680	10.9295	241.6585	41.6951	-30.8242	-2877	-0.00277	-10.4263	-1285	-0.02440
2300	4.9680	11.4263	242.1553	41.9159	-29.5918	-2770	-0.00407	-9.8452	-1231	-0.02348
2400	4.9680	11.9231	242.6521	42.1273	-28.4619	-2668	-0.00480	-9.3063	-1183	-0.02220
2500	4.9680	12.4199	243.1489	42.3301	-27.4219	-2562	-0.00569	-8.8134	-1138	-0.02111
2600	4.9680	12.9167	243.6457	42.5250	-26.4616	-2464	-0.00674	-8.3546	-1097	-0.02010
2700	4.9680	13.4135	244.1426	42.7126	-25.5719	-2363	-0.00777	-7.9282	-1058	-0.01944
2800	4.9680	13.9103	244.6393	42.8932	-24.7452	-2268	-0.00892	-7.5309	-1023	-0.01844
2900	4.9680	14.4071	245.1361	43.0675	-23.9749	-2179	-0.00983	-7.1597	-990	-0.01770
3000	4.9680	14.9039	245.6329	43.2359	-23.2554	-2095	-0.01090	-6.8120	-959	-0.01695
3100	4.9680	15.4007	246.1297	43.3988	-22.5816	-2016	-0.01178	-6.4857	-930	-0.01638
3200	4.9680	15.8975	246.6265	43.5565	-21.9492	-1921	-0.01268	-6.1787	-903	-0.01588
3300	4.9680	16.3943	247.1233	43.7094	-21.3544	-1850	-0.01354	-5.8894	-878	-0.01506
3400	4.9680	16.8911	247.6201	43.8577	-20.7938	-1802	-0.01444	-5.6161	-854	-0.01440
3500	4.9680	17.3879	248.1169	44.0017	-20.2645	-1748	-0.01524	-5.3577	-831	-0.01387
3600	4.9680	17.8847	248.6137	44.1417	-19.7637	-1696	-0.01598	-5.1129	-810	-0.01348
3700	4.9680	18.3815	249.1105	44.2778	-19.2891	-1649	-0.01645	-4.8805	-790	-0.01281
3800	4.9680	18.8783	249.6073	44.4103	-18.8387	-1603	-0.01707	-4.6597	-771	-0.01231
3900	4.9680	19.3751	250.1041	44.5393	-18.4106	-1561	-0.01745	-4.4497	-753	-0.01195
4000	4.9680	19.8719	250.6009	44.6651	-18.0029	-1520	-0.01787	-4.2495	-738	-0.01149
4100	4.9680	20.3687	251.0977	44.7878	-17.6143	-1481	-0.01836	-4.0585	-720	-0.01097
4200	4.9680	20.8655	251.5945	44.9075	-17.2433	-1444	-0.01869	-3.8781	-705	-0.01045
4300	4.9680	21.3623	252.0913	45.0244	-16.8888	-1410	-0.01895	-3.7017	-690	-0.01008
4400	4.9680	21.8591	252.5881	45.1386	-16.5494	-1376	-0.01922	-3.5348	-676	-0.00968
4500	4.9680	22.3559	253.0849	45.2502	-16.2244	-1345	-0.01941	-3.3749	-663	-0.00927
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	-0.01978	-3.0743	-639	-0.00858
4800	4.9680	23.8463	254.5753	45.5709	-15.3255	-1259	-0.01986	-2.9326	-628	-0.00814
4900	4.9680	24.3431	255.0721	45.6733	-15.0487	-1233	-0.01990	-2.7969	-616	-0.00770
5000	4.9680	24.8399	255.5689	45.7737	-14.7822	-1208	-0.01994	-2.6680	-605	-0.00737
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	-0.01967	-2.4185	-585	-0.00672
5300	4.9680	26.3303	257.0593	46.0632	-14.0386	-1142	-0.01942	-2.3014	-576	-0.00638
5400	4.9680	26.8271	257.5561	46.1560	-13.8077	-1122	-0.01930	-2.1884	-568	-0.00598
5500	4.9680	27.3239	258.0529	46.2472	-13.5844	-1103	-0.01904	-2.0792	-558	-0.00576
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	-0.01853	-1.8718	-541	-0.00532
5800	4.9680	28.8143	259.5433	46.5110	-12.9569	-1050	-0.01833	-1.7732	-534	-0.00499
5900	4.9680	29.3111	260.0401	46.5960	-12.7606	-1033	-0.01813	-1.6777	-526	-0.00473
6000	4.9680	29.8079	260.5369	46.6795	-12.5703			-1.5863		

TABLE XXXVII—THERMODYNAMIC PROPERTIES OF
 Li (GAS)

[Atomic weight, 6.940]

T (°K)	C_p ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)	$H_2 - H_0$ (kcal/mole)	H_f (kcal/mole)	S_f ($\frac{\text{cal}}{\text{mole } ^\circ\text{K}}$)
0	---	0	166.8941	---
298.16	4.9680	1.4509	168.3750	33.1418
300	4.9680	1.4604	168.3845	33.1734
350	4.9680	1.9672	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	4.9726	8.9428	175.8378	42.0763
1900	4.9776	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	43.9163
2700	5.1017	13.4591	180.3522	44.1082
2800	5.1332	13.9709	180.8620	44.2945
2900	5.1687	14.4859	181.3730	44.4730
3000	5.2083	15.0043	181.8869	44.6459
3100	5.2520	15.5278	182.4029	44.8124
3200	5.2997	16.0564	182.9215	44.9739
3300	5.3497	16.5909	183.4420	45.1308
3400	5.4034	17.1255	184.0646	45.2843
3500	5.4619	17.6688	184.6899	45.4348
3600	5.5223	18.2180	185.3171	45.5825
3700	5.5841	18.7733	185.9464	45.7286
3800	5.6495	19.3350	186.5781	45.8724
3900	5.7182	19.9034	187.2127	46.0140
4000	5.7870	20.4786	187.8507	46.1537
4100	5.8686	21.0609	188.4915	46.2915
4200	5.9516	21.6504	189.1345	46.4275
4300	6.0363	22.2473	189.7799	46.5619
4400	6.1218	22.8516	190.4277	46.6949
4500	6.1576	23.4636	191.0781	46.8264
4600	6.2356	24.0832	191.7313	46.9566
4700	6.3129	24.7106	192.3874	47.0855
4800	6.3919	25.3459	193.0467	47.2133
4900	6.4702	25.9890	193.7094	47.3401
5000	6.5496	26.6400	194.3757	47.4659
5100	6.6275	27.2988	195.0457	47.5917
5200	6.7059	27.9655	195.7194	47.7165
5300	6.7833	28.6399	196.3969	47.8403
5400	6.8608	29.3222	197.0784	47.9631
5500	6.9373	30.0121	197.7639	48.0859
5600	7.0130	30.7096	198.4534	48.2087
5700	7.0880	31.4146	199.1469	48.3315
5800	7.1617	32.1271	199.8444	48.4543
5900	7.2348	32.8469	200.5459	48.5771
6000	7.3068	33.5740	201.2514	48.7000

REPORT 1037—NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TABLE XXXVIII—THERMODYNAMIC PROPERTIES OF LiF (GAS)

[Molecular weight, 25.940]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H _f - H _g ($\frac{\text{kcal}}{\text{mole}}$)	H _f ($\frac{\text{kcal}}{\text{mole}}$)	S _f ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^{\circ}}{RT}$	$\delta \left(\frac{\Delta H^{\circ}}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$		log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0		0	77.9204							
298.16	7.0836	2.0786	80.0000	47.1209	233.2688			96.9767		
300	7.0872	2.0926	80.0130	47.1645	231.8488			95.4543		
400	7.3314	2.8129	80.7333	49.2849	174.2849			70.2551		
500	7.6048	3.5589	81.4802	50.9005	139.7116			55.1022		
600	7.8484	4.3328	82.2532	52.3092	110.6890			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	6.7877	84.6881	55.5935	78.0930			28.0630		
1000	8.4245	7.6655	85.5259	56.4761	70.3683	6981	0.02399	24.6694	3039	0.01707
1100	8.5016	8.4618	86.3722	57.2826	64.0434	6306	0.01920	21.8996	2765	0.01483
1200	8.5685	9.3050	87.2264	58.0250	58.7622	5785	-0.01560	19.5706	2536	-0.01353
1300	8.6137	10.1689	88.0843	58.7124	54.3036	5344	-0.01236	17.6063	2343	-0.01173
1400	8.6549	11.0273	88.9477	59.3528	50.4741	4965	-0.01050	15.9210	2177	-0.01077
1500	8.6930	11.8945	89.8149	59.9506	47.1536	4637	-0.00858	14.4589	2033	-0.00988
1600	8.7175	12.7649	90.6853	60.5123	44.2409	4350	0.00668	13.1784	1907	0.00904
1700	8.7416	13.6378	91.5582	61.0415	41.6814	4096	0.00564	12.0476	1796	0.00842
1800	8.7621	14.5130	92.4334	61.5417	39.4002	3871	0.00493	11.0414	1697	0.00774
1900	8.7796	15.3901	93.3105	62.0159	37.3585	3699	0.00330	10.1405	1609	0.00710
2000	8.7948	16.2688	94.1892	62.4696	35.5207	3488	0.00215	9.3289	1529	0.00650
2100	8.8079	17.1489	95.0693	62.8961	33.8576	3324	0.00109	8.5940	1457	0.00633
2200	8.8194	18.0308	95.9507	63.3061	32.3456	3176	-0.00037	7.9254	1392	-0.00578
2300	8.8295	18.9128	96.8332	63.6983	30.9851	3040	-0.00117	7.3144	1332	-0.00560
2400	8.8384	19.7961	97.7165	64.0743	29.6996	2917	-0.00280	6.7588	1277	-0.00540
2500	8.8463	20.6804	98.6008	64.4353	28.4836	2803	-0.00378	6.2376	1226	-0.00526
2600	8.8534	21.5664	99.4858	64.7824	27.4013	2698	-0.00486	5.7606	1179	-0.00523
2700	8.8597	22.4510	100.3714	65.1166	26.4669	2602	-0.00639	5.3189	1136	-0.00499
2800	8.8653	23.3372	101.2577	65.4389	25.5440	2512	-0.00731	4.9052	1095	-0.00511
2900	8.8704	24.2241	102.1445	65.7501	24.6851	2429	-0.00857	4.5255	1058	-0.00483
3000	8.8750	25.1118	103.0317	66.0509	23.8841	2351	-0.00969	4.1680	1023	-0.00480
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	-0.01160	3.5191	959	-0.00479
3300	8.8865	27.7756	105.6960	66.8973	21.7759	2146	-0.01248	3.2237	930	-0.00477
3400	8.8897	28.6644	106.5848	67.1627	21.1572	2088	-0.01337	2.9454	903	-0.00470
3500	8.8926	29.5535	107.4739	67.4204	20.5746	2030	-0.01439	2.6827	877	-0.00469
3600	8.8953	30.4429	108.3633	67.6710	20.0251	1975	-0.01473	2.4344	852	-0.00463
3700	8.8978	31.3326	109.2530	67.9147	19.5081	1925	-0.01568	2.1992	829	-0.00484
3800	8.9001	32.2228	110.1429	68.1620	19.0182	1878	-0.01674	1.9762	807	-0.00498
3900	8.9022	33.1126	111.0330	68.3832	18.5504	1830	-0.01780	1.7643	786	-0.00510
4000	8.9041	34.0029	111.9233	68.6087	18.1096	1787	-0.01785	1.5627	766	-0.00507
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	17.2936	1704	-0.01788	1.1877	729	-0.00517
4300	8.9092	36.6749	114.5953	69.2528	16.9181	1668	-0.01779	1.0130	712	-0.00526
4400	8.9107	37.5659	115.4863	69.4576	16.5548	1630	-0.01872	0.8459	696	-0.00528
4500	8.9121	38.4571	116.3775	69.6579	16.2113	1596	-0.01926	0.6860	680	-0.00537
4600	8.9134	39.3484	117.2688	69.8538	15.8836	1561	-0.01923	0.5328	665	-0.00541
4700	8.9146	40.2398	118.1602	70.0445	15.5707	1529	-0.01944	0.3859	651	-0.00538
4800	8.9157	41.1313	119.0517	70.2332	15.2716	1497	-0.01941	0.2449	636	-0.00560
4900	8.9168	42.0229	119.9433	70.4170	14.9855	1468	-0.01970	0.1095	623	-0.00570
5000	8.9178	42.9146	120.8350	70.5972	14.7116	1437	-0.01938	-0.0208	611	-0.00560
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	-0.01917	-0.2670	586	-0.00583
5300	8.9204	45.5904	123.5108	71.1169	13.9563	1355	-0.01833	-0.3834	575	-0.00592
5400	8.9212	46.4824	124.4028	71.2836	13.7247	1328	-0.01885	-0.4958	564	-0.00595
5500	8.9220	47.3746	125.2950	71.4474	13.5021	1303	-0.01878	-0.6043	553	-0.00606
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	-0.01828	-0.8104	534	-0.00603
5800	8.9240	50.0515	127.9719	71.9213	12.8844	1232	-0.01811	-0.9085	524	-0.00609
5900	8.9246	50.9439	128.8643	72.0738	12.6937	1209	-0.01780	-1.0034	515	-0.00617
6000	8.9252	51.8364	129.7568	72.2238	12.5100			-1.0954		

TABLE XXXIX--THERMODYNAMIC PROPERTIES OF LH (GAS)

[Molecular weight, 7.948]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H ₂ -H ₀ ($\frac{\text{kcal}}{\text{mole}}$)	H _f ($\frac{\text{kcal}}{\text{mole}}$)	S _f ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{-\Delta H^{\circ}}{RT}$	$s \left(\frac{-\Delta H^{\circ}}{RT} \right) = \frac{-sT}{100} \left(\frac{a}{T} + b \right)$		log K	$s \log K = \frac{-sT}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0		0	190.3225							
298.16	7.0763	2.0793	192.4018	40.7968	105.9833			41.7055		
300	7.0797	2.0923	192.4148	40.8398	106.3228			41.4293		
400	7.3176	2.8116	193.1940	42.9072	79.3373			29.8651		
500	7.6879	3.5508	193.8798	44.5692	63.7197			22.0611		
600	7.8318	4.3281	194.6506	45.9748	53.2862			18.4412		
700	8.0312	5.1216	195.4441	47.1973	45.8178			15.1301		
800	8.1899	5.9380	196.2668	48.2807	40.2082			12.6394		
900	8.3148	6.7856	197.0810	48.2629	35.8319			10.6968		
1000	8.4134	7.6931	197.9176	50.1842	32.3377	3136	0.02009	9.1888	1368	0.01598
1100	8.4918	8.4403	198.7628	50.9398	29.4507	2856	0.01550	7.9610	1294	0.01387
1200	8.5548	9.2927	199.6182	51.6814	27.0612	2621	0.01205	6.7938	1160	0.01269
1300	8.6060	10.1607	200.4732	52.4081	25.0320	2423	0.01019	5.8588	1072	0.01149
1400	8.6481	11.0134	201.3359	53.0074	23.2911	2242	0.00877	5.1116	997	0.01033
1500	8.6829	11.8899	202.2024	53.6063	21.7810	2104	0.00780	4.4366	932	0.00930
1600	8.7121	12.7497	203.0722	54.1866	20.4687	1975	0.006574	3.8448	875	0.00839
1700	8.7357	13.6221	203.9446	54.6956	19.2912	1861	0.00451	3.3217	824	0.00812
1800	8.7676	14.4969	204.8194	55.1955	18.2328	1759	0.00371	2.8558	780	0.00707
1900	8.7756	15.3735	205.6990	55.6694	17.3232	1669	0.00230	2.4382	739	0.00700
2000	8.7911	16.2518	206.5743	56.1200	16.4665	1588	0.00121	2.0617	703	0.00644
2100	8.8046	17.1816	207.4541	56.5492	15.7291	1514	0.00042	1.7205	670	0.00625
2200	8.8162	18.0127	208.3352	56.9691	15.0405	1448	-0.00037	1.4097	640	0.00604
2300	8.8266	18.8948	209.2173	57.3812	14.4118	1387	-0.00172	1.1254	613	0.00558
2400	8.8358	19.7779	210.1004	57.7270	13.8356	1332	-0.00290	0.8644	588	0.00530
2500	8.8439	20.6619	210.9844	58.0879	13.3067	1282	-0.00428	0.6299	565	0.00519
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	58.7891	12.3646	1193	-0.00647	0.1951	524	0.00486
2800	8.8634	23.3182	213.6407	59.0913	11.9450	1154	-0.00778	0.0031	505	0.00456
2900	8.8686	24.2048	214.5273	59.4024	11.5548	1117	-0.00883	-0.1769	486	0.00483
3000	8.8733	25.0918	215.4143	59.7032	11.1913	1083	-0.00975	-0.3434	472	0.00464
3100	8.8776	25.9794	216.3019	59.9942	10.8517	1052	-0.01115	-0.5001	457	0.00459
3200	8.8816	26.8673	217.1898	60.2761	10.5341	1021	-0.01169	-0.6477	445	0.00456
3300	8.8851	27.7557	218.0782	60.5495	10.2368	993	-0.01256	-0.7865	429	0.00472
3400	8.8884	28.6444	218.9669	60.8145	9.9568	969	-0.01416	-0.9174	417	0.00456
3500	8.8918	29.5333	219.8558	61.0724	9.6941	943	-0.01454	-1.0411	404	0.00473
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	61.5687	9.2135	897	-0.01535	-1.2692	383	0.00461
3800	8.8990	32.2019	222.5244	61.8040	8.9934	877	-0.01687	-1.3746	373	0.00466
3900	8.9011	33.0919	223.4144	62.0352	8.7854	854	-0.01670	-1.4749	363	0.00476
4000	8.9032	33.9821	224.3046	62.2695	8.5886	836	-0.01760	-1.5704	354	0.00476
4100	8.9050	34.8726	225.1951	62.4984	8.4023	817	-0.01792	-1.6615	345	0.00486
4200	8.9068	35.7631	226.0856	62.6950	8.2267	798	-0.01808	-1.7485	336	0.00506
4300	8.9084	36.6539	226.9764	62.9046	8.0582	783	-0.01885	-1.8317	328	0.00505
4400	8.9099	37.5448	227.8678	63.1094	7.8991	765	-0.01880	-1.9113	321	0.00507
4500	8.9113	38.4395	228.7584	63.3097	7.7479	750	-0.01924	-1.9877	313	0.00526
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	-0.01970	-2.1313	299	0.00541
4800	8.9150	41.1098	231.4323	63.8849	7.3369	704	-0.01947	-2.1990	292	0.00561
4900	8.9161	42.0014	232.3239	64.0688	7.2127	691	-0.01970	-2.2642	285	0.00570
5000	8.9171	42.8933	233.2166	64.2489	7.0942	673	-0.01926	-2.3269	279	0.00579
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	-0.01935	-2.4459	267	0.00602
5300	8.9199	45.5686	235.8911	64.7698	6.7700	637	-0.01936	-2.5023	262	0.00608
5400	8.9207	46.4606	236.7831	64.9383	6.6714	624	-0.01905	-2.5568	257	0.00607
5500	8.9216	47.3527	237.6782	65.0990	6.5770	611	-0.01881	-2.6096	251	0.00628
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	-0.01841	-2.7103	241	0.00645
5800	8.9236	50.0295	240.3520	65.5729	6.3174	576	-0.01823	-2.7583	236	0.00660
5900	8.9242	50.9219	241.2444	65.7254	6.2389	564	-0.01780	-2.8049	232	0.00663
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 ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$H_p - H_p^0$ (kcal/mole)	H_p (kcal/mole)	S_p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)
0		0	85.0606	—
298.16	4.9680	1.4812	87.4508	38.6145
300	4.9680	1.4904	87.4600	38.6450
400	4.9680	1.9672	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	43.0968
1200	4.9680	5.9616	91.9312	43.5321
1300	4.9680	6.4584	92.4280	43.9267
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	9.4392	95.4088	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	46.7648
2400	4.9746	11.9246	97.8942	46.9763
2500	4.9777	12.4222	98.3918	47.1794
2600	4.9816	12.9202	98.8896	47.3747
2700	4.9869	13.4188	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	18.9763	104.9461	49.2890
3900	5.1844	19.4928	105.4632	49.4253
4000	5.2143	20.0135	105.9831	49.5599
4100	5.2461	20.5365	106.5061	49.6930
4200	5.2800	21.0628	107.0324	49.8259
4300	5.3158	21.5926	107.5622	49.9585
4400	5.3533	22.1261	108.0957	50.0912
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	110.2698	50.5309
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	30.6626	116.6321	51.7216
6000	6.1179	31.2716	117.2412	51.8268

TABLE XII—THERMODYNAMIC PROPERTIES OF N₂ (GAS)

[Molecular weight, 28.016]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{K}}$)	H _f -H ₂₉₈ (kcal/mole)	H _f (kcal/mole)	S _f ($\frac{\text{cal}}{\text{mole} \cdot \text{K}}$)	$\frac{\Delta H^\circ}{RT}$	$\ln \left(-\frac{\Delta H^\circ}{RT} - \frac{-5T}{100} \left(\frac{a}{T} + b \right) \right)$		log K	$\delta \log K = \frac{-5T}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0		0	1.6992							
298.16	6.960	2.0723	3.7715	45.787	288.8283			119.4348		
300	6.961	2.0851	3.7843	45.809	287.0664			118.6656		
400	6.991	2.7824	4.4818	47.818	215.6725			87.4738		
500	7.070	3.4850	5.1842	49.885	172.8306			68.7259		
600	7.197	4.1950	5.8972	50.685	144.2610			56.2064		
700	7.351	4.9283	6.6245	51.805	123.8438			47.2492		
800	7.512	5.6886	7.3678	52.797	108.5207			40.5214		
900	7.671	6.4280	8.1272	53.662	96.5897			35.2815		
1000	7.816	7.2025	8.9017	54.5090	87.0447	8.665	0.02284	31.0841	3768	0.02405
1100	7.947	7.9907	9.6899	55.2801	79.2255	7790	0.02943	27.6455	3418	0.02057
1200	8.063	8.7912	10.4904	55.9855	72.7044	7145	0.02594	24.7766	3186	0.01779
1300	8.165	9.6026	11.3018	56.6300	67.1823	6500	0.02241	22.3485	2988	0.01510
1400	8.253	10.4285	12.1227	57.2143	62.4456	6153	0.01923	20.2614	2803	0.01347
1500	8.330	11.2826	12.9518	57.7363	58.3377	5727	0.01732	18.4826	2615	0.01233
1600	8.399	12.0691	13.7883	58.2611	54.7410	5373	0.01481	16.8684	2380	0.01076
1700	8.459	12.9320	14.6312	58.7871	51.5636	5060	0.01309	15.4894	2228	0.00970
1800	8.512	13.7805	15.4797	59.3221	48.7414	4781	0.01185	14.2247	2101	0.00881
1900	8.560	14.6341	16.3333	59.7836	46.2182	4532	0.01080	13.1101	1991	0.00830
2000	8.602	15.4922	17.1914	60.2227	43.9867	4308	0.00927	12.1063	1893	0.00757
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	0.00702	10.3703	1728	0.00647
2300	8.705	18.0890	19.7882	61.4333	38.2901	3753	0.00595	9.6147	1649	0.00602
2400	8.733	18.9609	20.6601	61.8044	36.7204	3599	0.00490	8.9216	1581	0.00570
2500	8.759	19.8365	21.5347	62.1614	35.2769	3457	0.00419	8.2835	1519	0.00527
2600	8.783	20.7126	22.4118	62.5054	33.9421	3327	0.00298	7.6940	1461	0.00499
2700	8.805	21.5920	23.2912	62.8373	32.7099	3207	0.00174	7.1479	1407	0.00480
2800	8.825	22.4735	24.1727	63.1579	31.5598	3096	0.00061	6.6404	1357	0.00477
2900	8.844	23.3570	25.0562	63.4679	30.4916	2992	0.00043	6.1677	1311	0.00460
3000	8.8610	24.2422	25.9414	63.7680	29.4947	2896	0.00169	5.7261	1268	0.00427
3100	8.8774	25.1291	26.8283	64.0588	28.5622	2806	-0.00268	5.3128	1227	0.00436
3200	8.8928	26.0177	27.7160	64.3409	27.6880	2722	-0.00396	4.9280	1189	0.00420
3300	8.9073	26.9077	28.6069	64.6148	26.8671	2644	-0.00525	4.5605	1153	0.00415
3400	8.9210	27.7991	29.4983	64.8809	26.0947	2570	-0.00628	4.2172	1120	0.00398
3500	8.9340	28.6918	30.3910	65.1397	25.3667	2501	-0.00772	3.8983	1088	0.00388
3600	8.9462	29.5858	31.2850	65.3915	24.6797	2436	-0.00873	3.5972	1058	0.00385
3700	8.9577	30.4810	32.1802	65.6363	24.0301	2375	-0.01020	3.2974	1029	0.00391
3800	8.9686	31.3773	33.0766	65.8758	23.4153	2317	-0.01140	3.0227	1002	0.00398
3900	8.9790	32.2747	33.9739	66.1089	22.8326	2262	-0.01240	2.7618	976	0.00400
4000	8.9890	33.1731	34.8723	66.3364	22.2795	2210	-0.01362	2.5138	952	0.00390
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	2112	-0.01570	2.0827	906	0.00410
4300	9.0174	35.8741	37.5733	66.9875	20.7787	2068	-0.01660	1.8879	885	0.00406
4400	9.0263	36.7763	38.4755	67.1949	20.3253	2028	-0.01772	1.6827	864	0.00420
4500	9.0350	37.6794	39.3786	67.3979	19.8928	1984	-0.01840	1.4865	845	0.00420
4600	9.0435	38.5833	40.2825	67.5965	19.4799	1945	-0.01923	1.2986	827	0.00414
4700	9.0518	39.4881	41.1873	67.7911	19.0853	1907	-0.02009	1.0985	809	0.00426
4800	9.0600	40.3937	42.0929	67.9818	18.7081	1870	-0.02083	0.8957	792	0.00427
4900	9.0681	41.3001	42.9993	68.1687	18.3470	1835	-0.02120	0.7286	776	0.00450
5000	9.0760	42.2073	43.9065	68.3520	18.0012	1801	-0.02184	0.5703	759	0.00448
5100	9.0838	43.1163	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	-0.02284	0.2693	729	0.00475
5300	9.0991	44.9336	46.6325	68.8815	17.0472	1706	-0.02313	0.1270	714	0.00498
5400	9.1066	45.8438	47.5420	69.0518	16.7544	1677	-0.02361	0.0102	700	0.00513
5500	9.1140	46.7549	48.4541	69.2188	16.4731	1648	-0.02389	0.0000	686	0.00530
5600	9.1214	47.6666	49.3658	69.3881	16.2027	1620	-0.02421	-0.2704	673	0.00543
5700	9.1287	48.5791	50.2783	69.5446	15.9427	1594	-0.02453	-0.3939	661	0.00553
5800	9.1359	49.4924	51.1916	69.7084	15.6924	1568	-0.02486	-0.5134	648	0.00577
5900	9.1431	50.4063	52.1055	69.8696	15.4515	1543	-0.02507	-0.6290	637	0.00583
6000	9.1502	51.3210	53.0202	70.0134	15.2194			-0.7410		

TABLE XLII—THERMODYNAMIC PROPERTIES OF NO (GAS)

[Molecular weight, 30.008]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H _f - H ₃ ($\frac{\text{kcal}}{\text{mole}}$)	H _f ($\frac{\text{kcal}}{\text{mole}}$)	S _f ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^\circ}{RT}$	$d\left(\frac{-\Delta H^\circ}{RT}\right) = \frac{-dT}{100} \left(\frac{a}{T} + b\right)$		log K	$d \log K = \frac{-dT}{100} \left(\frac{c}{T} + d\right)$	
						a	b		c	d
0	7.187	0	23.3447	50.339	207.8039			84.8403		
298.16	7.134	2.2068	25.5515	50.394	204.5399			84.2876		
300	7.162	2.9208	26.2855	52.436	165.2832			61.8373		
400	7.289	3.4440	26.7887	54.048	124.5125			48.3348		
500	7.468	4.3812	27.7259	55.892	108.9835			39.3132		
600	7.587	5.1836	28.4818	56.556	89.3040			32.8556		
700	7.633	5.9096	29.2843	57.589	78.2839			28.0035		
800	7.690	6.7005	30.0452	58.820	69.7015			24.2228		
900	7.769	7.5090	30.8507	59.3700	62.8276	6160	0.03020	21.1937	2707	0.02129
1000	8.243	8.3245	31.6992	60.1500	57.1974	5806	0.02857	18.7115	2465	0.01723
1100	8.342	9.1637	32.4984	60.8715	52.5009	5143	0.02155	16.6401	2262	0.01500
1200	8.426	9.9921	33.3368	61.5425	48.6232	4751	0.01873	14.8861	2090	0.01334
1300	8.498	10.8383	34.1890	62.1696	45.1109	4415	0.01637	13.3769	1943	0.01147
1400	8.560	11.6912	35.0359	62.7580	42.1512	4124	0.01410	12.0721	1815	0.01033
1500	8.614	12.5499	35.8946	63.3122	39.5596	3869	0.01232	10.9274	1708	0.00944
1600	8.660	13.4136	36.7583	63.8388	37.2714	3644	0.01086	9.9162	1604	0.00859
1700	8.702	14.2817	37.6264	64.3319	35.2361	3444	0.00937	9.0185	1516	0.00791
1800	8.738	15.1537	38.4984	64.8034	33.4141	3265	0.00830	8.2107	1437	0.00740
1900	8.771	16.0292	39.3739	65.2524	31.7733	3104	0.00711	7.4848	1367	0.00645
2000	8.801	16.9078	40.2525	65.6811	30.2981	2958	0.00616	6.8274	1302	0.00598
2100	8.828	17.7892	41.1339	66.0912	28.9374	2826	0.00520	6.2263	1244	0.00553
2200	8.852	18.6732	42.0179	66.4841	27.7035	2704	0.00478	5.6826	1191	0.00505
2300	8.874	19.5585	42.9042	66.8613	26.5721	2593	0.00410	5.1811	1142	0.00450
2400	8.895	20.4450	43.7927	67.2240	25.5303	2491	0.00332	4.7193	1097	0.00398
2500	8.914	21.3384	44.6831	67.5732	24.5694	2399	0.00235	4.2927	1056	0.00349
2600	8.932	22.2307	45.5754	67.9100	23.6789	2311	0.00154	3.8973	1017	0.00319
2700	8.949	23.1245	46.4699	68.2351	22.8520	2229	0.00103	3.5299	981	0.00292
2800	8.966	24.0205	47.3652	68.5494	22.0820	2156	0.00073	3.1875	945	0.00265
2900	8.981	24.9179	48.2626	68.8537	21.3632	2086	0.00060	2.8677	910	0.00239
3000	8.996	25.8167	49.1614	69.1484	20.6909	2021	-0.00138	2.5693	887	0.00271
3100	9.010	26.7170	50.0617	69.4342	20.0607	1961	-0.00224	2.2874	866	0.00300
3200	9.024	27.6187	50.9634	69.7117	19.4687	1904	-0.00310	2.0233	846	0.00331
3300	9.037	28.5218	51.8665	69.9813	18.9118	1851	-0.00396	1.7745	810	0.00367
3400	9.049	29.4261	52.7708	70.2432	18.3868	1800	-0.00450	1.5397	787	0.00399
3500	9.061	30.3316	53.6768	70.4985	17.8913	1753	-0.00528	1.3178	765	0.00334
3600	9.073	31.2383	54.5830	70.7469	17.4228	1708	-0.00597	1.1077	745	0.00315
3700	9.085	32.1463	55.4909	70.9891	16.9798	1666	-0.00668	0.9085	726	0.00290
3800	9.096	33.0552	56.3999	71.2252	16.5583	1626	-0.00740	0.7194	707	0.00265
3900	9.107	33.9654	57.3101	71.4556	16.1597	1588	-0.00812	0.5395	689	0.00235
4000	9.118	34.8769	58.2218	71.6806	15.7805	1552	-0.00872	0.3682	673	0.00200
4100	9.128	35.7899	59.1336	71.9005	15.4197	1518	-0.00952	0.2050	656	0.00165
4200	9.138	36.7022	60.0469	72.1154	15.0762	1486	-0.01000	0.0492	641	0.00122
4300	9.148	37.6155	60.9612	72.3256	14.7487	1453	-0.01039	-0.0997	627	0.00077
4400	9.158	38.5318	61.8765	72.5312	14.4362	1422	-0.01063	-0.2422	612	0.00030
4500	9.168	39.4481	62.7928	72.7326	14.1377	1393	-0.01108	-0.3785	599	0.00026
4600	9.178	40.3654	63.7101	72.9299	13.8524	1365	-0.01148	-0.5092	586	0.00032
4700	9.188	41.2837	64.6284	73.1232	13.5795	1335	-0.01176	-0.6346	574	0.00036
4800	9.198	42.2030	65.5477	73.3128	13.3182	1313	-0.01220	-0.7651	561	0.00050
4900	9.208	43.1233	66.4680	73.4987	13.0673	1288	-0.01255	-0.8708	550	0.00056
5000	9.218	44.0446	67.3893	73.6912	12.8278	1264	-0.01288	-0.9522	539	0.00055
5100	9.227	44.9669	68.3116	73.8802	12.5974	1240	-0.01276	-1.0804	525	0.00068
5200	9.237	45.8901	69.2345	74.0651	12.3762	1218	-0.01306	-1.1927	517	0.00080
5300	9.246	46.8142	70.1589	74.2085	12.1637	1196	-0.01315	-1.2823	507	0.00092
5400	9.256	47.7393	71.0840	74.3786	11.9594	1175	-0.01332	-1.3384	497	0.00105
5500	9.266	48.6654	72.0101	74.5454	11.7629	1155	-0.01353	-1.4812	488	0.00109
5600	9.275	49.5925	72.9372	74.7095	11.5738	1136	-0.01366	-1.5709	478	0.00429
5700	9.285	50.5206	73.8652	74.8709	11.3916	1117	-0.01382	-1.6576	469	0.00441
5800	9.294	51.4484	74.7941	75.0297	11.2161	1099	-0.01397	-1.7415	461	0.00447
5900	9.304	52.3763	75.7240	75.1860	11.0469			-1.8228		

TABLE XLIII—THERMODYNAMIC PROPERTIES OF O (GAS)

[Atomic weight, 16.0000]

T (°K)	C_p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$H_f - H_0$ ($\frac{\text{kcal}}{\text{mole}}$)	H_f ($\frac{\text{kcal}}{\text{mole}}$)	S_f ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)
0	-----	0	59.6041	-----
298.16	5.2364	1.6074	61.2115	38.4889
300	5.2336	1.6170	61.2211	38.5010
400	5.1241	2.1249	61.7390	39.9915
500	5.0602	2.6454	62.2496	41.1908
600	5.0456	3.1517	62.7558	42.0540
700	5.0264	3.6555	63.2596	42.5807
800	5.0150	4.1576	63.7617	43.0611
900	5.0085	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	6.1576	65.7617	45.6288
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	47.5482
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	71.2403	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	50.4188
3300	5.0245	16.6328	76.2369	50.5728
3400	5.0326	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	51.5462
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	5.1376	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 O₂ (GAS)

[Molecular weight, 32.000]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H _f - H _f ⁰ ($\frac{\text{kcal}}{\text{mole}}$)	H _f ⁰ ($\frac{\text{kcal}}{\text{mole}}$)	S _f ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^0}{RT}$	$s \left(\frac{\Delta H^0}{RT} - \frac{-sT}{100} \left(\frac{a}{T} + b \right) \right)$		log K	$\log K = \frac{-sT}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0	-----	0	2.0362	-----	-----	-----	-----	-----	-----	-----
288.16	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	4.8329	51.098	149.2819	-----	-----	58.8109	-----	-----
500	7.431	3.5288	5.5650	52.728	119.7013	-----	-----	45.5311	-----	-----
600	7.670	4.2841	6.3203	54.106	99.9689	-----	-----	36.8580	-----	-----
700	7.883	5.0620	7.0982	55.303	85.8510	-----	-----	30.6499	-----	-----
800	8.063	5.8596	7.8968	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	58.190	60.2812	5926	0.02853	19.4400	2804	0.01823
1100	8.439	8.3400	10.3762	58.963	54.9654	5392	0.02417	17.0545	2370	0.01550
1200	8.527	9.1883	11.2245	59.734	50.4479	4947	.02061	15.0640	2178	.01322
1300	8.604	10.0448	12.0810	60.420	46.8220	4569	.01873	13.3777	2009	.01200
1400	8.674	10.9087	12.9449	61.022	43.8396	4245	.01700	11.9307	1867	.01083
1500	8.738	11.7793	13.8153	61.628	40.4928	3963	.01642	10.6752	1744	.00960
1600	8.800	12.6562	14.6924	62.237	37.9998	3717	0.01623	9.5756	1637	0.00826
1700	8.858	13.5391	15.5753	62.7640	35.7976	3490	.01501	8.6044	1542	.00743
1800	8.916	14.4278	16.4640	63.2719	33.8787	3305	.01473	7.7403	1468	.00643
1900	8.973	15.3223	17.3585	63.7585	32.0845	3132	.01420	6.9665	1385	.00550
2000	9.029	16.2224	18.2586	64.2172	30.4043	2976	.01386	6.2695	1315	.00491
2100	9.084	17.1280	19.1642	64.6590	28.9738	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	18.9568	20.9920	65.4904	26.6809	2580	.01283	4.5398	1146	.00370
2400	9.248	19.8779	21.9141	65.8828	25.6889	2464	.01200	4.0586	1099	.00330
2500	9.301	20.8054	22.8416	66.2614	24.8333	2366	.01161	3.6167	1056	.00295
2600	9.354	21.7381	23.7743	66.6272	23.9540	2295	0.01120	3.2066	1016	0.00260
2700	9.405	22.6761	24.7123	66.9812	23.0928	2212	.01080	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	27.4385	29.4760	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	18.070	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	33.3687	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	35.3206	70.2756	16.1813	1594	.00278	-.0304	700	.00071
3900	9.901	34.2829	36.2919	70.5323	15.7698	1555	.00225	-.2106	682	.00070
4000	9.932	35.2745	37.2617	70.7834	15.3788	1519	.00161	-.3818	665	.00070
4100	9.960	36.2691	38.2353	71.0280	15.0067	1484	0.00107	-.5447	649	0.00068
4200	9.987	37.2665	39.2027	71.2698	14.6523	1450	.00069	-.6999	634	.00056
4300	10.013	38.2665	40.1627	71.5046	14.3144	1419	.00010	-.8479	619	.00062
4400	10.037	39.2690	41.1152	71.7351	13.9918	1388	-.00014	-.9892	606	.00043
4500	10.060	40.2738	42.0610	71.9609	13.6835	1359	-.00063	-1.1243	592	.00050
4600	10.081	41.2809	43.0171	72.1822	13.3887	1331	-.00089	-1.2535	579	0.00051
4700	10.103	42.2901	44.0263	72.3993	13.1064	1304	-.00127	-1.3772	567	.00048
4800	10.121	43.3013	45.0375	72.6122	12.8360	1279	-.00162	-1.4958	555	.00053
4900	10.139	44.3143	46.0505	72.8210	12.5766	1254	-.00190	-1.6096	543	.00060
5000	10.156	45.3290	47.0652	73.0261	12.3277	1230	-.00208	-1.7188	533	.00049
5100	10.172	46.3454	48.0816	73.2278	12.0886	1207	-.00232	-1.8238	522	0.00062
5200	10.187	47.3634	49.0996	73.4250	11.8588	1184	-.00240	-1.9248	512	.00060
5300	10.201	48.3828	50.1190	73.6192	11.6378	1163	-.00248	-2.0220	502	.00064
5400	10.215	49.4036	51.1398	73.8100	11.4251	1143	-.00252	-2.1156	493	.00056
5500	10.228	50.4257	52.1619	73.9976	11.2201	1123	-.00256	-2.2058	484	.00057
5600	10.239	51.4490	53.1858	74.1819	11.0226	1102	-.00253	-2.2928	475	0.00067
5700	10.250	52.4735	54.2097	74.3632	10.8322	1084	-.00210	-2.3768	466	.00076
5800	10.261	53.4991	55.2353	74.5416	10.6483	1067	-.00235	-2.4579	458	.00077
5900	10.270	54.5256	56.2618	74.7171	10.4709	1049	-.00243	-2.5363	450	.00080
6000	10.279	55.5531	57.2893	74.8898	10.2995	-----	-----	-2.6121	-----	-----

TABLE XLV—THERMODYNAMIC PROPERTIES OF OH (GAS)

[Molecular weight, 17.008]

T (°K)	C _p ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	H ₂ -H ₀ ($\frac{\text{kcal}}{\text{mole}}$)	H _f ($\frac{\text{kcal}}{\text{mole}}$)	S _f ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^\circ}{RT}$	$\delta \left(\frac{-\Delta H^\circ}{RT} - \frac{-\delta T}{100} \left(\frac{a}{T} + b \right) \right)$		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	44.8328	43.888	170.7827			69.3677		
300	7.139	2.1225	44.8491	43.984	169.7395			68.9110		
400	7.074	2.8298	47.5562	45.978	127.6916			50.4585		
500	7.048	3.5360	48.2616	47.558	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	64.5888			22.6043		
900	7.234	6.3774	51.1040	51.723	57.6682			19.4838		
1000	7.333	7.1060	51.8328	52.4910	51.9494	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	43.8001	4194	0.02915	13.2113	1863	.02172
1300	7.668	9.3549	54.0815	54.4559	40.2448	3873	0.02777	11.7865	1728	.01909
1400	7.772	10.1288	54.8532	55.0278	37.4506	3599	0.02607	10.5067	1603	.01678
1500	7.875	10.9090	55.6356	55.5675	35.0262	3361	0.02478	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	0.02210	7.6285	1327	.01198
1800	8.152	13.3142	58.0408	57.0285	29.3496	2808	0.02041	6.8793	1255	.01087
1900	8.233	14.1333	58.8601	57.4714	27.8513	2663	0.01890	6.2979	1190	.01020
2000	8.308	14.9605	59.6871	57.8956	26.6009	2538	0.01731	5.8027	1133	.00938
2100	8.378	15.7948	60.5214	58.3027	25.5774	2415	0.01617	5.3842	1080	0.00839
2200	8.443	16.6369	61.3625	58.6939	24.1635	2308	0.01482	4.5549	1032	.00790
2300	8.504	17.4832	62.2098	59.0705	22.1482	2210	0.01387	4.0983	989	.00710
2400	8.561	18.3365	63.0631	59.4337	20.2105	2121	0.01290	3.6792	949	.00650
2500	8.614	19.1952	63.9218	59.7842	21.3495	2038	0.01185	3.2931	912	.00608
2600	8.663	20.0591	64.7857	60.1230	20.5638	1962	0.01083	2.9363	878	0.00581
2700	8.710	20.9277	65.6543	60.4508	19.8162	1892	0.00999	2.6055	846	.00548
2800	8.756	21.8010	66.5276	60.7684	19.1003	1826	0.00934	2.2979	817	.00528
2900	8.798	22.6789	67.4052	61.0764	18.4115	1765	0.00877	2.0113	790	.00487
3000	8.838	23.5604	68.2870	61.3753	17.8444	1708	0.00813	1.7434	764	.00455
3100	8.877	24.4462	69.1728	61.6658	17.3358	1655	0.00741	1.4926	740	0.00415
3200	8.913	25.3367	70.0623	61.9482	16.8710	1605	0.00694	1.2572	716	.00372
3300	8.949	26.2288	70.9554	62.2230	16.4437	1558	0.00646	1.0369	697	.00360
3400	8.982	27.1233	71.8519	62.4906	16.0537	1513	0.00621	.8273	677	.00327
3500	9.015	28.0202	72.7518	62.7515	15.6942	1471	0.00579	.6306	659	.00304
3600	9.047	28.9283	73.6549	63.0069	14.9898	1432	0.00527	0.4445	641	0.00286
3700	9.077	29.8345	74.5611	63.2542	14.6075	1395	0.00489	.2884	624	.00279
3800	9.107	30.7437	75.4703	63.4966	14.2355	1369	0.00464	.1614	606	.00270
3900	9.135	31.6568	76.3824	63.7356	13.8824	1325	0.00435	-.0572	593	.00255
4000	9.162	32.5706	77.2972	63.9662	13.5468	1293	0.00413	-.2080	579	.00238
4100	9.189	33.4882	78.2148	64.1917	13.2273	1263	0.00379	-.3516	565	0.00228
4200	9.215	34.4084	79.1360	64.4135	12.9228	1234	0.00352	-.4884	552	.00223
4300	9.241	35.3312	80.0573	64.6306	12.6323	1206	0.00321	-.6190	539	.00220
4400	9.266	36.2565	80.9831	64.8434	12.3549	1179	0.00280	-.7437	526	.00197
4500	9.290	37.1843	81.9109	65.0518	12.0897	1154	0.00238	-.8630	517	.00181
4600	9.314	38.1145	82.8411	65.2563	11.8358	1129	0.00209	-.9772	506	0.00174
4700	9.338	39.0471	83.7737	65.4569	11.5927	1106	0.00228	-1.0866	495	.00178
4800	9.362	39.9821	84.7087	65.6537	11.3596	1084	0.00253	-1.1915	485	.00172
4900	9.384	40.9194	85.6460	65.8470	11.1358	1062	0.00256	-1.2922	476	.00160
5000	9.406	41.8589	86.5856	66.0368	10.9209	1041	0.00248	-1.3890	468	.00163
5100	9.427	42.8006	87.5272	66.2228	10.7143	1021	0.00235	-1.4820	458	0.00152
5200	9.448	43.7443	88.4709	66.4065	10.5156	1002	0.00214	-1.5716	449	.00148
5300	9.469	44.6902	89.4168	66.5867	10.3244	984	0.00208	-1.6578	440	.00152
5400	9.489	45.6381	90.3647	66.7639	10.1401	966	0.00206	-1.7408	433	.00187
5500	9.509	46.5880	91.3146	66.9352	9.9624	949	0.00194	-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	93.2208	67.2785	9.6266	916	0.00187	-1.9728	411	.00124
5800	9.567	49.4495	94.1781	67.4447	9.4683	901	0.00179	-2.0449	404	.00123
5900	9.585	50.4071	95.1377	67.6084	9.3113	886	0.00168	-2.1146	397	.00123
6000	9.603	51.3665	96.0991	67.7697	9.1620			-2.1820		