NASA TN D-2

7N-28
194159
P 56

TECHNICAL NOTE

D-2

APPROXIMATE COMPOSITION AND THERMODYNAMIC PROPERTIES

OF NONIONIZED NITROGEN-OXYGEN MIXTURES

By Richard A. Hord

Langley Research Center
Langley Field, Va.

(NASA-TN-D-2) APPROXIMATE COMPOSITION AND THERMODYNAMIC PROPERTIES OF NONIONIZED NITROGEN-OXYGEN MIXTURES (NASA. Langley Research Center) 56 p

N89-71403

Unclas
00/28 0194159

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON August 1959

01

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL NOTE D-2

APPROXIMATE COMPOSITION AND THERMODYNAMIC PROPERTIES OF NONIONIZED NITROGEN-OXYGEN MIXTURES

By Richard A. Hord

SUMMARY

With account taken of molecular vibrations, dissociation, and electronic excitation but with ionization and nitric oxide formation neglected, analytic expressions are derived for the composition and thermodynamic properties of nitrogen-oxygen mixtures. Thermodynamic properties are tabulated by using some of these expressions. Since the composition expressions become inaccurate when temperature and density favor the presence of considerable nitric oxide, the assumption of negligible nitric oxide is removed, and solution by iteration is used to prepare composition tables for the chemical species N, O, N_2, O_2, and NO. For densities sufficiently high for ionization to be negligible, the results of the study are applicable to 10,000° K.

INTRODUCTION

For the calculation of flow fields in hypersonic aerodynamics, the properties of air at high temperatures are required. These properties fall into two categories depending upon whether the processes with which a small volume of air is involved are (practically) reversible or irreversible in the thermodynamic sense. The first, or reversible, category includes thermodynamic or equilibrium properties (compressibility factor, enthalpy, entropy, and so forth). The second, or irreversible, category includes transport properties (thermal conductivity, viscosity, and so forth) and characteristic times of relaxation (for excitation of molecular vibrations, dissociation of molecules, and so forth).

The thermodynamic properties of air at high temperatures have been calculated by Gilmore (ref. 1), Hilsenrath and Beckett (ref. 2), Logan and Treanor (ref. 3), and others. Several transport properties of air have been calculated by Greifinger (ref. 4) and Hansen (ref. 5), for example. Hirschfelder (ref. 6) and Butler and Brokaw (ref. 7) recently discussed the effect of chemical reactions on thermal conductivity. Radiative heat transfer has been investigated by Meyerott (ref. 8) and others. Relaxation phenomena in general have been reviewed by Herzfeld

(ref. 9), but a great deal of theoretical and experimental work concerned with air has been done more recently.

The unwieldy mathematical expressions usually encountered in the accurate calculation of the thermodynamic properties of an ideal gas mixture by means of statistical thermodynamics often necessitate the presentation of the results in tabular form. While this form is adequate for many applications, it is often advantageous in theoretical analyses, even at the expense of some sacrifice in accuracy, to have analytic expressions for the physical properties involved. Accordingly, one of the main purposes of the present study has been to obtain such expressions for the thermodynamic properties of air.

Another purpose has been to extend the calculations to mixtures in which the proportion of nitrogen to oxygen is not the same as that found in air (in the denser portion of the atmosphere). Since the dissociation energy of nitrogen is much larger than that of oxygen, it appears likely that flow fields will be encountered in hypersonic aerodynamics in which a diffusive partial separation of the nitrogen and oxygen components occurs. This partial separation may also take place in the flow of air over a surface which is undergoing oxidation at a sufficiently rapid rate.

In this study approximate analytic expressions are developed for the composition and thermodynamic properties of nitrogen-oxygen mixtures. The chief limitations of these expressions are: (1) the assumption of negligible ionization, and (2) the assumption of very small nitric oxide formation. The first assumption is not a serious one over the range of temperatures and densities considered. In the case of thermodynamic properties, the errors resulting from the second assumption are, for most purposes, not serious (cf. ref. 5). The expressions for the composition, however, become rather inaccurate in the range in which nitric oxide is formed to a considerable extent. Consequently, in order to complement the analytic expressions for the composition, the assumption of very small nitric oxide formation was removed, and solution by iteration was employed in order to prepare composition tables for the chemical species N, O, N_2, O_2, and NO. These tables can, in turn, be used to prepare somewhat more accurate tables of thermodynamic properties.

The exact thermodynamic expressions presented in appendix A may also prove useful in computing the speed of sound, isentropic exponent, and specific heats of any gas mixture for which the compressibility factor and internal energy are known in terms of temperature and density (rather than temperature and pressure).

SYMBOLS

a	low-frequency speed of sound
A	work function (Helmholtz free energy), per unit mass
$(B_0)_i$	rotational constant for molecule of ith species ($i = 3,4,5$)
c	speed of light
c_p	specific heat (per unit mass) at constant pressure
c_v	specific heat (per unit mass) at constant volume (or constant density)
D_i	dissociation energy of one molecule of ith species (corresponds to the D_0 of spectroscopic literature)
e	base of natural logarithms
E	internal energy per unit mass
g_{ni}	statistical weight of nth electronic energy level of one atom (molecule) of ith species
$G_0(1)$	oscillator wave number (see ref. 11)
h	Planck constant
H	enthalpy per unit mass
k	Boltzmann constant
ln	natural logarithm
m_i	mass of one atom (molecule) of ith species
n_i	number of atoms (molecules) of ith species in given quantity of gas
$n_{3,0}$	number of nitrogen molecules given quantity of gas would contain at standard conditions
$n_{4,0}$	number of oxygen molecules given quantity of gas would contain at standard conditions

N	nitrogen (atomic species)
N_2	nitrogen (molecular species)
N_{ch}	Avogadro number (chemical scale)
NO	nitric oxide
O	oxygen (atomic species)
O_2	oxygen (molecular species)
p	pressure
q_i	partition function of one atom (molecule) of ith species in the given volume
$q_i^{(tr)}$	translational partition function of one atom (molecule) of ith species in the given volume
$q_i^{(int)}$	internal partition function of one atom (molecule) of ith species
$q_i^{(rot)}$	rotational partition function of one molecule of ith species
$q_i^{(vib)}$	vibrational partition function of one molecule of ith species
$q_i^{(elec)}$	electronic partition function of one atom (molecule) of ith species
Q	partition function of the given quantity of gas
r	integer corresponding to highest electronic energy level considered
R	gas constant, per unit mass, at standard conditions (cf. eqs. (15) and (16))
S	entropy per unit mass
t_{ni}	characteristic temperature of nth electronic energy level of one atom (molecule) of ith species
$\bar{t}_i$	mean characteristic temperature for electronic excitation of one atom (molecule) of ith species

T	temperature, absolute
v_0	volume per molecule at standard conditions
V	volume of given quantity of gas
X_i	mole fraction of ith species
Z	compressibility factor (cf. eqs. (15) and (16))
α	fraction of nitrogen in gas mixture, $\frac{n_{3,0}}{n_{3,0} + n_{4,0}}$
β	fraction of oxygen in gas mixture, $\frac{n_{4,0}}{n_{3,0} + n_{4,0}}$
δ_i	ground-state energy of atom (molecule) of ith species
ϵ_i	ratio of mean energy of one atom (molecule) of ith species to kT
θ_i	characteristic temperature for vibration of molecule of ith species (cf. eqs. (48))
λ_1	absolute activity of atomic nitrogen in gas mixture
λ_2	absolute activity of atomic oxygen in gas mixture
μ_1	chemical potential of atomic nitrogen in gas mixture
μ_2	chemical potential of atomic oxygen in gas mixture
ν_i	ratio of number of atoms (molecules) of ith species to total number of molecules at standard conditions (cf. eqs. (34))
ξ_1	nitrogen dissociation parameter (eq. (14a))
ξ_2	oxygen dissociation parameter (eq. (14b))
ρ	density
σ_i	symmetry number for molecule of ith species

L
1
7
9

τ_i temperature function for atom (molecule) of ith species, $\frac{\rho}{\rho_0}\left(\frac{q_i}{n_{3,0} + n_{4,0}}\right)$

ϕ $\frac{\ln Q}{n_{3,0} + n_{4,0}}$ (cf. eq. (30))

Subscripts:

0 refers to standard conditions (273° K at 1 atmosphere)

1 refers to atomic nitrogen

2 refers to atomic oxygen

3 refers to molecular nitrogen

4 refers to molecular oxygen

5 refers to nitric oxide

L
1
7
9

COMPOSITION AND THERMODYNAMIC PROPERTIES OF THE GAS MIXTURE

Consider a mixture of $n_{3,0}$ molecules of N_2 and $n_{4,0}$ molecules of O_2, where the subscript zero refers to standard conditions of temperature and pressure (273° K at 1 atmosphere). At arbitrary temperature and pressure let n_1, n_2, n_3, n_4, and n_5 denote the numbers of N, O, N_2, O_2, and NO molecules, respectively. Then, the conservation equations

$$n_1 + 2n_3 + n_5 = 2n_{3,0} \tag{1a}$$

$$n_2 + 2n_4 + n_5 = 2n_{4,0} \tag{1b}$$

apply. When the five species are in thermochemical equilibrium, statistical thermodynamics (see, for example, ref. 10) gives, for the composition of the ideal gas mixture,

$$n_1 = q_1\lambda_1 \tag{2a}$$

$$n_2 = q_2\lambda_2 \tag{2b}$$

$$n_3 = q_3\lambda_1^2 \tag{2c}$$

$$n_4 = q_4\lambda_2^2 \tag{2d}$$

L
1
7
9

$$n_5 = q_5\lambda_1\lambda_2 \tag{2e}$$

where q_i is the partition function of one molecule of the ith species and λ_1 and λ_2 are the absolute activities of N and O, respectively; λ_1 and λ_2 are related to the corresponding chemical potentials (per atom) μ_1 and μ_2 by

$$\lambda_1 = e^{\mu_1/kT} \tag{3a}$$

$$\lambda_2 = e^{\mu_2/kT} \tag{3b}$$

where k is the Boltzmann constant and T is the absolute temperature. The partition function Q of the gas mixture, from which the thermodynamic properties are derived, is given by

$$\ln Q = \sum_{i=1}^{5} n_i\left(1 + \ln \frac{q_i}{n_i}\right) \tag{4}$$

By using equations (1) and (2), equation (4) can be put into the form

$$\ln Q = \frac{1}{2} q_1\lambda_1 + \frac{1}{2} q_2\lambda_2 + n_{3,0}(1 - 2 \ln \lambda_1) + n_{4,0}(1 - 2 \ln \lambda_2) \tag{5}$$

Upon defining quantities ϕ, $\tau_i (i = 1,\ldots,5)$, α, and β as

$$\phi = \frac{\ln Q}{n_{3,0} + n_{4,0}} \tag{6}$$

$$\tau_i = \frac{\rho}{\rho_0}\left(\frac{q_i}{n_{3,0} + n_{4,0}}\right) \tag{7}$$

$$\alpha = \frac{n_{3,0}}{n_{3,0} + n_{4,0}} \tag{8a}$$

$$\beta = \frac{n_{4,0}}{n_{3,0} + n_{4,0}} \tag{8b}$$

L
1
7
9

where ρ/ρ_0 denotes the ratio of the density of the gas mixture to its density at the standard conditions of temperature and pressure, equation (5) can be expressed as

$$\phi = 1 + \frac{1}{2}\frac{\rho_0}{\rho}\left(\tau_1\lambda_1 + \tau_2\lambda_2\right) - 2\alpha \ln \lambda_1 - 2\beta \ln \lambda_2 \tag{9}$$

From equations (1), (2), (7), and (8) it follows that the absolute activities λ_1 and λ_2 are positive roots of the coupled algebraic equations

$$\tau_1\lambda_1 + 2\tau_3\lambda_1^2 + \tau_5\lambda_1\lambda_2 = 2\alpha \frac{\rho}{\rho_0} \tag{10a}$$

$$\tau_2\lambda_2 + 2\tau_4\lambda_2^2 + \tau_5\lambda_1\lambda_2 = 2\beta \frac{\rho}{\rho_0} \tag{10b}$$

or, if nitric oxide is neglected, of the independent quadratic equations

$$\tau_1\lambda_1 + 2\tau_3\lambda_1^2 = 2\alpha \frac{\rho}{\rho_0} \tag{11a}$$

$$\tau_2\lambda_2 + 2\tau_4\lambda_2^2 = 2\beta\,\frac{\rho}{\rho_0} \tag{11b}$$

When the positive roots of equations (11) are substituted for λ_1 and λ_2, equation (9) can be written in the form

$$\phi = 1 + \alpha \ln \frac{\tau_3}{\alpha} + \beta \ln \frac{\tau_4}{\beta} + \ln \frac{\rho_0}{\rho} + \alpha f\left(\xi_1\right) + \beta f\left(\xi_2\right) \tag{12}$$

where, by definition,

$$f\left(\xi_j\right) = 2\xi_j\left(\sqrt{1 + \xi_j^2} - \xi_j\right) - 2 \ln\left(\sqrt{1 + \xi_j^2} - \xi_j\right) \qquad (j = 1,2) \tag{13}$$

and

$$\xi_1 = \frac{\tau_1 \Big/ 4\tau_3^{1/2}}{\left(\alpha\rho/\rho_0\right)^{1/2}} \tag{14a}$$

$$\xi_2 = \frac{\tau_2 \Big/ 4\tau_4^{1/2}}{\left(\beta\rho/\rho_0\right)^{1/2}} \tag{14b}$$

The last two terms on the right of equation (12) constitute the additive correction due to dissociation, which is, as is ϕ itself, a dimensionless ratio of (Helmholtz) free energy to the absolute temperature. Equation (12) essentially expresses ϕ in terms of the proportions α and β of nitrogen and oxygen in the gas mixture, the density ratio, and the temperature functions τ_i of the individual molecules; the development of explicit approximate expressions for the τ_i is considered subsequently.

The gas constant (per unit mass) for the mixture at and near the standard conditions of temperature and pressure is given by

$$R = \frac{\text{(Universal gas constant, per mole)}}{\text{(Mass per mole at standard conditions)}}$$

$$= \frac{k}{\alpha m_3 + \beta m_4} \tag{15}$$

where m_3 and m_4 are the masses of individual molecules of N_2 and O_2, respectively. Thus, the equation of state for the mixture is

$$\frac{p}{\rho RT} = Z \tag{16}$$

where Z is the compressibility factor; at and near the standard conditions of temperature and pressure, $Z = 1$ accurately.

By statistical thermodynamics,

$$Z = -\frac{\rho}{\rho_0}\left[\frac{\partial\phi}{\partial\left(\rho/\rho_0\right)}\right]_T \tag{17}$$

Equations (12) and (17) give

$$Z = 1 + \frac{1}{2}\alpha\xi_1 f'\left(\xi_1\right) + \frac{1}{2}\beta\xi_2 f'\left(\xi_2\right) \tag{18}$$

where the two derivatives $f'\left(\xi_1\right)$ and $f'\left(\xi_2\right)$ are, from equations (13), given by

$$f'\left(\xi_j\right) = 4\left(\sqrt{1 + \xi_j^2} - \xi_j\right) \qquad (j = 1,2) \tag{19}$$

By using equations (19), equation (18) for the compressibility factor becomes

$$Z = 1 + 2\alpha\xi_1\left(\sqrt{1 + \xi_1^2} - \xi_1\right) + 2\beta\xi_2\left(\sqrt{1 + \xi_2^2} - \xi_2\right) \tag{20}$$

By denoting the internal energy per unit mass for the gas mixture by E and using equation (12) again, one obtains

$$\frac{E}{RT} = T\left(\frac{\partial \phi}{\partial T}\right)_\rho$$

$$= \alpha T \frac{d \ln \tau_3}{dT} + \beta T \frac{d \ln \tau_4}{dT} + \alpha T f'\left(\xi_1\right)\left(\frac{\partial \xi_1}{\partial T}\right)_\rho + \beta T f'\left(\xi_2\right)\left(\frac{\partial \xi_2}{\partial T}\right)_\rho \tag{21}$$

From equations (14), the temperature derivatives of $\left(\xi_1\right)$ and $\left(\xi_2\right)$ can be expressed as

$$\left(\frac{\partial \xi_1}{\partial T}\right)_\rho = \xi_1\left(\frac{d \ln \tau_1}{dT} - \frac{1}{2}\frac{d \ln \tau_3}{dT}\right) \tag{22a}$$

$$\left(\frac{\partial \xi_2}{\partial T}\right)_\rho = \xi_2\left(\frac{d \ln \tau_2}{dT} - \frac{1}{2}\frac{d \ln \tau_4}{dT}\right) \tag{22b}$$

Let ϵ_i denote the ratio of the mean energy of one molecule of the ith species to kT. Then,

$$\epsilon_i = T\left(\frac{\partial \ln q_i}{\partial T}\right)_\rho \tag{23}$$

or, by using equation (7),

$$\epsilon_i = T \frac{d \ln \tau_i}{dT} \tag{24}$$

Equations (21), (22), and (24) yield

$$\frac{E}{RT} = \alpha\epsilon_3 + \beta\epsilon_4 + \alpha\xi_1 f'\left(\xi_1\right)\left(\epsilon_1 - \frac{1}{2}\epsilon_3\right) + \beta\xi_2 f'\left(\xi_2\right)\left(\epsilon_2 - \frac{1}{2}\epsilon_4\right) \tag{25}$$

which is analogous in form to equation (18). By applying equations (19), equation (25) becomes

$$\frac{E}{RT} = \alpha\epsilon_3 + \beta\epsilon_4 + 2\alpha\xi_1\left(\sqrt{1 + \xi_1^2} - \xi_1\right)\left(2\epsilon_1 - \epsilon_3\right) +$$

$$2\beta\xi_2\left(\sqrt{1 + \xi_2^2} - \xi_2\right)\left(2\epsilon_2 - \epsilon_4\right) \tag{26}$$

The interpretation of equations (20) and (26) becomes clear when q_1, q_2, λ_1, and λ_2 are eliminated from equations (2a) and (2b) by using equations (7), (11), and (14). The resulting composition equations for the atomic species N and O are, respectively,

$$\frac{\frac{1}{2} n_1}{n_{3,0} + n_{4,0}} = 2\alpha\xi_1\left(\sqrt{1 + \xi_1^2} - \xi_1\right) \tag{27a}$$

$$\frac{\frac{1}{2} n_2}{n_{3,0} + n_{4,0}} = 2\beta\xi_2\left(\sqrt{1 + \xi_2^2} - \xi_2\right) \tag{27b}$$

The approximate expression for the enthalpy H (per unit mass) follows directly from the identity

$$\frac{H}{RT} = \frac{E}{RT} + Z \tag{28}$$

and from equations (20) and (26); that is,

$$\frac{H}{RT} = 1 + \alpha\epsilon_3 + \beta\epsilon_4 + 2\alpha\xi_1\left(\sqrt{1 + \xi_1^2} - \xi_1\right)\left(1 + 2\epsilon_1 - \epsilon_3\right) +$$

$$2\beta\xi_2\left(\sqrt{1 + \xi_2^2} - \xi_2\right)\left(1 + 2\epsilon_2 - \epsilon_4\right) \tag{29}$$

Statistical thermodynamics relates the work function or Helmholtz free energy A, per unit mass, to the quantity ϕ through the equation

$$\frac{A}{RT} = -\phi \tag{30}$$

Hence, equations (12), (13), and (30) yield

$$-\frac{A}{RT} = 1 + \alpha \ln \frac{\tau_3}{\alpha} + \beta \ln \frac{\tau_4}{\beta} + \ln \frac{\rho_0}{\rho} +$$

$$2\alpha\xi_1\left(\sqrt{1 + \xi_1^2} - \xi_1\right) - 2\alpha \ln\left(\sqrt{1 + \xi_1^2} - \xi_1\right) +$$

$$2\beta\xi_2\left(\sqrt{1 + \xi_2^2} - \xi_2\right) - 2\beta \ln\left(\sqrt{1 + \xi_2^2} - \xi_2\right) \tag{31}$$

L
1
7
9

The identity relating the entropy S (per unit mass) of the gas mixture to A, E, and T, namely,

$$\frac{S}{R} = \frac{E}{RT} - \frac{A}{RT} \tag{32}$$

together with equations (26) and (31) gives

$$\frac{S}{R} = 1 + \alpha\left(\epsilon_3 + \ln \frac{\tau_3}{\alpha}\right) + \beta\left(\epsilon_4 + \ln \frac{\tau_4}{\beta}\right) + \ln \frac{\rho_0}{\rho} +$$

$$2\alpha\xi_1\left(\sqrt{1 + \xi_1^2} - \xi_1\right)\left(1 + 2\epsilon_1 - \epsilon_3\right) - 2\alpha \ln\left(\sqrt{1 + \xi_1^2} - \xi_1\right) +$$

$$2\beta\xi_2\left(\sqrt{1 + \xi_2^2} - \xi_2\right)\left(1 + 2\epsilon_2 - \epsilon_4\right) - 2\beta \ln\left(\sqrt{1 + \xi_2^2} - \xi_2\right) \tag{33}$$

For the chemical composition of the gas mixture, let ratios ν_i be defined according to the equations

$$\nu_i = \frac{n_i}{n_{3,0} + n_{4,0}} \qquad (i = 1,\ldots,5) \tag{34}$$

By using equations (8) and (34), equations (1) become

$$\nu_1 + 2\nu_3 + \nu_5 = 2\alpha \tag{35a}$$

$$\nu_2 + 2\nu_4 + \nu_5 = 2\beta \tag{35b}$$

By applying equations (7) and (34), equations (2) take the forms

$$\nu_1 = \frac{\rho_0}{\rho} \tau_1 \lambda_1 \tag{36a}$$

$$\nu_2 = \frac{\rho_0}{\rho} \tau_2 \lambda_2 \tag{36b}$$

L
1
7
9

$$\nu_3 = \frac{\rho_0}{\rho} \tau_3 \lambda_1^2 \tag{36c}$$

$$\nu_4 = \frac{\rho_0}{\rho} \tau_4 \lambda_2^2 \tag{36d}$$

$$\nu_5 = \frac{\rho_0}{\rho} \tau_5 \lambda_1 \lambda_2 \tag{36e}$$

Replacing λ_1 and λ_2 in equations (36) by the positive roots of equations (11) gives

$$\nu_1 = 4\alpha\xi_1\left(\sqrt{1 + \xi_1^2} - \xi_1\right) \tag{37a}$$

$$\nu_2 = 4\beta\xi_2\left(\sqrt{1 + \xi_2^2} - \xi_2\right) \tag{37b}$$

$$\nu_3 = \alpha\left(\sqrt{1 + \xi_1^2} - \xi_1\right)^2 \tag{37c}$$

$$\nu_4 = \beta\left(\sqrt{1 + \xi_2^2} - \xi_2\right)^2 \tag{37d}$$

$$\nu_5 = \sqrt{\alpha\beta \frac{\tau_5^2}{\tau_3\tau_4}}\left(\sqrt{1 + \xi_1^2} - \xi_1\right)\left(\sqrt{1 + \xi_2^2} - \xi_2\right) \tag{37e}$$

Equations (37a) and (37b) correspond to equations (27a) and (27b) derived previously.

Two extreme cases are especially interesting when the composition equations (37) are applied to air, for which $\alpha = 0.78847$ and $\beta = 0.21153$ (cf. ref. 2):

Case (1).- Lower temperatures and higher densities $\left(\text{for example, } T = 2{,}000^\circ\ \text{K and } \frac{\rho}{\rho_0} = 1\right)$. In this case, $\xi_1,\ \xi_2 \ll 1$, $\sqrt{1 + \xi_j^2} - \xi_j \approx 1$, $\nu_1 \ll \nu_3 \approx \alpha$, $\nu_2 \ll \nu_4 \approx \beta$, and $\nu_5 \approx \sqrt{\alpha\beta \frac{\tau_5^2}{\tau_3\tau_4}}$. ($\nu_5$ is of the order of 0.01.) Thus, the degree of dissociation is small, and the nitric oxide parameter ν_5 is primarily a monotonic increasing function of the temperature.

L
1
7
9

Case (2).- Higher temperatures and lower densities $\left(\text{for example, } T = 5{,}000^\circ\ \text{K and } \frac{\rho}{\rho_0} = 10^{-6}\right)$. In this case, $\xi_1 > 1$, $\xi_2 \gg 1$, $\sqrt{1 + \xi_j^2} - \xi_j \approx \frac{1}{2\xi_j}$, $\nu_3 \ll \nu_1 \approx 2\alpha$, $\nu_4 \ll \nu_2 \approx 2\beta$, and $\nu_5 \ll 0.01$. Dissociation is nearly complete.

Situations between case (1) and case (2) are not so simple. With increasing temperature and decreasing density, the progress of the dissociation of oxygen leads that of nitrogen primarily because of the much larger dissociation energy of the N_2 molecule.

The significance of ξ_1 and ξ_2 as measures of the degrees of dissociation of nitrogen and oxygen, respectively, can also be seen from the following equations, which can be derived from equations (37a) to (37d).

$$\xi_1 = \frac{1}{4}\frac{\nu_1}{\nu_3}\frac{1}{\sqrt{1 + \frac{1}{2}\frac{\nu_1}{\nu_3}}} \tag{38a}$$

$$\xi_2 = \frac{1}{4}\frac{\nu_2}{\nu_4}\frac{1}{\sqrt{1 + \frac{1}{2}\frac{\nu_2}{\nu_4}}} \tag{38b}$$

Evaluation of Temperature Functions

It is necessary to obtain suitable expressions for the parameters τ_i and ϵ_i as functions of temperature and for the dissociation parameters ξ_j as functions of temperature and density. For each atom or molecule, the partition function q_i can be expressed as the product of a translational partition function $q_i^{(tr)}$, an internal partition function $q_i^{(int)}$, and an exponential factor containing the ground-state energy δ_i of the particle. Thus,

$$q_i = q_i^{(tr)} q_i^{(int)} e^{-\delta_i/kT} \tag{39}$$

L
1
7
9

By referring all energies to the ground states of the N_2 and O_2 molecules, one obtains

$$\delta_1 = \frac{1}{2} D_3 \tag{40a}$$

$$\delta_2 = \frac{1}{2} D_4 \tag{40b}$$

$$\delta_3 = 0 \tag{40c}$$

$$\delta_4 = 0 \tag{40d}$$

$$\delta_5 = \frac{1}{2} D_3 + \frac{1}{2} D_4 - D_5 \tag{40e}$$

where D_i is the dissociation energy of one molecule of the ith species ($i = 3,4,5$). (Note that D here corresponds to the D_0 of the literature of spectroscopy). The translational partition function $q_i(tr)$ is given by

$$q_i^{(tr)} = \frac{(2\pi m_i kT)^{3/2} V}{h^3} \tag{41}$$

where m_i is the mass of the particle, V is the volume of the given quantity of gas, and h is the Planck constant. Equations (7), (39), and (41) yield

$$\tau_i = \frac{\alpha m_3 + \beta m_4}{\rho_0} \frac{\left(2\pi m_i kT\right)^{3/2}}{h^3} q_i(\text{int}) e^{-\delta_i/kT} \tag{42}$$

where the ratio

$$v_0 = \frac{\alpha m_3 + \beta m_4}{\rho_0} \tag{43}$$

is, by the definition of ρ_0, simply the volume per molecule at the standard conditions and is, therefore, independent of the ratio α/β of nitrogen to oxygen in the gas mixture. Consistent with frequent practice in chemistry, nuclear partition functions need not be included in formulating the internal partition functions $q_i^{(\text{int})}$. Then, for each atom, $q_i^{(\text{int})}$ is simply the corresponding electronic partition function; that is,

$$q_i^{(\text{int})} = q_i^{(\text{elec})} \qquad (i = 1,2) \tag{44}$$

For each molecule the internal partition function can be expressed, with sufficient accuracy for this study, as a product of rotational, vibrational, and electronic partition functions; that is,

$$q_i^{(\text{int})} = q_i^{(\text{rot})} q_i^{(\text{vib})} q_i^{(\text{elec})} \qquad (i = 3,4,5) \tag{45}$$

For a rigid rotator, the classical (integrated) form of the partition function is

$$q_i^{(\text{rot})} = \frac{T}{\sigma_i (hc/k)\left(B_0\right)_i} \qquad (i = 3,4,5) \tag{46}$$

where σ_i is the symmetry number (accounting for the effects of nuclear spin); c is the speed of light, and $\left(B_0\right)_i$ is the rotational constant.

(See ref. 11.) For a harmonic oscillator, the partition function can be expressed as

$$q_i^{(vib)} = \frac{1}{1 - e^{-\left[G_0(1)\right]_i (hc/k)/T}} \qquad (i = 3,4,5) \tag{47}$$

The use here of $G_0(1)$, rather than ω_e as the oscillator wave number has the advantage of accounting for the initial effects of oscillator anharmonicity. (See ref. 11 for precise meanings of these symbols.) In order to simplify the notation in equations (47), it is convenient to define characteristic temperatures for vibration according to the equations

$$\theta_i = \left[G_0(1)\right]_i hc/k \qquad (i = 3,4,5) \tag{48}$$

Approximations for Molecular $\left(N_2, \ O_2\right)$ Parameters

Applicable in Whole Temperature Range

By using equations (40) to (48), except (41) and (44), one obtains for the N_2 and O_2 molecules $(i = 3,4)$:

$$\tau_i = \frac{\left(2\pi m_i kT\right)^{3/2} v_0}{h^3} \frac{T}{\sigma_i (hc/k)(B_0)_i} \frac{1}{1 - e^{-\theta_i/T}} q_i^{(elec)} \tag{49}$$

The four dimensionless factors on the right correspond to the translational, rotational, vibrational, and electronic modes, respectively.

Since the nuclei of the N_2 molecules are identical, the symmetry number σ_3 is equal to 2; similarly, for O_2 the symmetry number σ_4 is equal to 2. Since, in the temperature-density range considered, the molecules N_2 and O_2 are nearly all dissociated before their excited electronic states are appreciably populated, the electronic partition functions are adequately approximated by the statistical weights of the ground states; that is,

$$q_3^{(elec)} = 1 \tag{50a}$$

$$q_4^{(elec)} = 3 \tag{50b}$$

Consequently, equations (49) reduce to

$$\tau_3 = \frac{\left(2\pi m_3 k\right)^{3/2} v_0}{2h^3 (hc/k)\left(B_0\right)_3} \frac{T^{5/2}}{1 - e^{-\theta_3/T}} \tag{51a}$$

$$\tau_4 = \frac{3\left(2\pi m_4 k\right)^{3/2} v_0}{2h^3 (hc/k)\left(B_0\right)_4} \frac{T^{5/2}}{1 - e^{-\theta_4/T}} \tag{51b}$$

Equations (24) and (51) yield the following expressions for the energy parameters:

$$\epsilon_3 = \frac{5}{2} + \frac{\theta_3/T}{e^{\theta_3/T} - 1} \tag{52a}$$

$$\epsilon_4 = \frac{5}{2} + \frac{\theta_4/T}{e^{\theta_4/T} - 1} \tag{52b}$$

The terms 5/2 in equations (52) reflect, of course, the equipartition of energy in the three translational degrees of freedom $\left(\text{total energy, } \frac{3}{2}\,kT\right)$ and the two rotational ones (total energy, kT). In each of equations (52) the vibrational contribution to ϵ_i increases from practically zero at low temperatures to values approaching the equipartition value (unity) at high temperatures. In cases of aerodynamic interest, however, the dissociation of N_2 or O_2 is practically complete at temperatures sufficiently high for the simple equipartition approximation to apply to vibrational excitation with good accuracy; this condition is largely due to the wide spacing of the vibrational energy levels. The possibility of equipartition in the case of vibrations is, of course, ultimately precluded by the fact that the vibrational energy of an actual molecule is, unlike that of the ideal harmonic oscillator, bounded by the dissociation energy.

Simple Approximations for Atomic and Molecular Parameters Applicable at Higher Temperatures

The excited electronic states of the N atom lie sufficiently high on the energy scale to be effectively out of reach in the temperature range considered here. Consequently, the electronic partition function of the N atom is taken as the statistical weight of the ground state; that is,

$$q_1^{(elec)} = 4 \tag{53}$$

The O atom and the NO molecule, on the other hand, both have electronic states (above the ground state) for which the excitation energies are low enough not to be negligible. This added complication in the mathematical expressions for the τ_i can be removed with negligible loss of accuracy by the following method.

The electronic partition function is of the form

$$q_i^{(elec)} = \sum_{n=0}^{r} g_{ni} e^{-t_{ni}/T} \tag{54}$$

where g_{ni} and t_{ni} are, respectively, the statistical weight and characteristic temperature of the nth energy level. By using the power series expansions for the exponential functions, equation (54) becomes

$$\begin{aligned} q_i^{(elec)} &= \sum_{n=0}^{r} g_{ni}\left(1 - \frac{t_{ni}}{T} + \ldots\right) \\ &= \left(\sum_{n=0}^{r} g_{ni}\right) - \frac{\left(\sum_{n=0}^{r} g_{ni} t_{ni}\right)}{T} + \ldots \\ &= \left(\sum_{n=0}^{r} g_{ni}\right)\left[1 - \frac{\left(\dfrac{\sum_{n=0}^{r} g_{ni} t_{ni}}{\sum_{n=0}^{r} g_{ni}}\right)}{T} + \ldots\right] \end{aligned} \tag{55}$$

At sufficiently high temperatures the power series in brackets is approximately equal to the exponential function

$$e^{-\bar{t}_i/T}$$

where

L
1
7
9

$$\bar{t}_i = \frac{\left(\sum_{n=0}^{r} g_{ni} t_{ni}\right)}{\sum_{n=0}^{r} g_{ni}} \tag{56}$$

Thus, the approximate expression for the electronic partition function is

$$q_i^{(elec)} = \left(\sum_{n=0}^{r} g_{ni}\right) e^{-\bar{t}_i/T} \tag{57}$$

With the application of the high-temperature approximation method expressed in equation (57), the electronic partition functions (see, for example, refs. 11 and 12)

$$q_2^{(elec)} = 5 + 3e^{-t_{12}/T} + e^{-t_{22}/T} \tag{58a}$$

$$q_5^{(elec)} = 2 + 2e^{-t_{15}/T} \tag{58b}$$

(for the O atom and the NO molecule, respectively) become

$$q_2^{(elec)} = 9e^{-\bar{t}_2/T} \tag{59a}$$

$$\bar{t}_2 = \frac{3t_{12} + t_{22}}{9} \tag{59b}$$

$$q_5^{(elec)} = 4e^{-\bar{t}_5/T} \tag{59c}$$

$$\bar{t}_5 = \frac{2t_{15}}{4} \tag{59d}$$

In each case the error introduced is less than 1 percent for $T > 1{,}000^\circ$ K (except, of course, for very high temperatures).

In order to obtain concise expressions for the dissociation parameters ξ_1 and ξ_2, simple high-temperature approximations for the vibrational partition functions of the diatomic molecules N_2 and O_2 are useful and may be developed as follows:

By using the power-series expansion for the exponential function, equations (47) and (48) yield

$$q_i^{(vib)} = \left\{1 - \left[1 - \frac{\theta_i}{T} + \frac{1}{2!}\left(\frac{\theta_i}{T}\right)^2 - \cdot\cdot\cdot\right]\right\}^{-1}$$

$$= \left[\frac{\theta_i}{T}\left(1 - \frac{1}{2}\frac{\theta_i}{T} + \cdot\cdot\cdot\right)\right]^{-1} \tag{60}$$

For high temperatures, this equation is approximately

$$q_i^{(vib)} = \left(\frac{\theta_i}{T} e^{-\theta_i/2T}\right)^{-1}$$

$$= \frac{T}{\theta_i} e^{\theta_i/2T} \tag{61}$$

The error involved in this approximation is less than 4 percent when $T > \theta_i$. Since the use of the approximation is restricted to the simplification of terms which become negligibly small at the lower temperatures, this rather large inaccuracy is not representative of the outcome of its application.

Final Forms for Temperature Functions and Dissociation Parameters

By collecting the results from equations (40) to (61), the high-temperature approximations for the temperature functions τ_i of the atoms and molecules become

L
1
7
9

$$\tau_1 = \frac{4\left(2\pi m_1 k\right)^{3/2} v_0}{h^3} T^{3/2} e^{-\left(\frac{D_3}{2k}\right)/T} \tag{62a}$$

$$\tau_2 = \frac{9\left(2\pi m_2 k\right)^{3/2} v_0}{h^3} T^{3/2} e^{-\left(\frac{D_4}{2k} + \bar{t}_2\right)/T} \tag{62b}$$

$$\tau_3 = \frac{\left(2\pi m_3 k\right)^{3/2} v_0}{2h^3 (hc/k)\left(B_0\right)_3 \theta_3} T^{7/2} e^{\left(\frac{\theta_3}{2}\right)/T} \tag{62c}$$

$$\tau_4 = \frac{3\left(2\pi m_4 k\right)^{3/2} v_0}{2h^3 (hc/k)\left(B_0\right)_4 \theta_4} T^{7/2} e^{\left(\frac{\theta_4}{2}\right)/T} \tag{62d}$$

$$\tau_5 = \frac{4\left(2\pi m_5 k\right)^{3/2} v_0}{h^3 (hc/k)\left(B_0\right)_5 \theta_5} T^{7/2} e^{-\left(\frac{D_3+D_4-2D_5}{2k} - \frac{\theta_5}{2} + \bar{t}_5\right)/T} \tag{62e}$$

The quantities $\left(2\epsilon_1 - \epsilon_3\right)$ and $\left(2\epsilon_2 - \epsilon_4\right)$ appearing in the high-temperature terms of the internal-energy equation (26) and subsequent equations can be evaluated by using equations (24) and (62a) to (62d). Thus,

$$2\epsilon_1 - \epsilon_3 = 2\left(\frac{3}{2} + \frac{D_3/2k}{T}\right) - \left(\frac{7}{2} - \frac{\theta_3/2}{T}\right)$$

$$= \left(\frac{D_3}{k} + \frac{\theta_3}{2}\right)\frac{1}{T} - \frac{1}{2} \tag{63a}$$

$$2\epsilon_2 - \epsilon_4 = 2\left(\frac{3}{2} + \frac{\bar{t}_2 + D_4/2k}{T}\right) - \left(\frac{7}{2} - \frac{\theta_4/2}{T}\right)$$

$$= \left(\frac{D_4}{k} + \frac{\theta_4}{2} + 2\bar{t}_2\right)\frac{1}{T} - \frac{1}{2} \tag{63b}$$

L
1
7
9

The required approximate expressions for the dissociation parameters ξ_1 and ξ_2 are derived from equations (14) and equations (62a) to (62d) with $m_3 = 2m_1$ and $m_4 = 2m_2$. These expressions are:

$$\xi_1 = \frac{1}{\alpha^{1/2}}\left[2\left(\frac{\pi m_1 k}{h^2}\right)^{3/2} v_0 \frac{hc}{k}(B_0)_3\theta_3\right]^{1/2} \frac{e^{-\frac{1}{2}\left(\frac{D_3}{k} + \frac{\theta_3}{2}\right)/T}}{\left(T^{1/2}\rho/\rho_0\right)^{1/2}} \tag{64a}$$

$$\xi_2 = \frac{1}{\beta^{1/2}}\left[\frac{27}{8}\left(\frac{\pi m_2 k}{h^2}\right)^{3/2} v_0 \frac{hc}{k}(B_0)_4\theta_4\right]^{1/2} \frac{e^{-\frac{1}{2}\left(\frac{D_4}{k} + \frac{\theta_4}{2} + 2\bar{t}_2\right)/T}}{\left(T^{1/2}\rho/\rho_0\right)^{1/2}} \tag{64b}$$

Explicit Expressions for Composition

The calculation of the amount of nitric oxide in the gas mixture by utilizing equation (37e) requires an explicit expression for the ratio $\tau_5^2/\tau_3\tau_4$. The latter can be found from equations (62c) to (62e).

The evaluation of the composition equations (37a) to (37d) requires only the expressions (64) for ξ_1 and ξ_2.

The resulting approximate expressions for the ν_i are fairly accurate except in the ionization range, which corresponds to higher temperatures and lower densities, and in the nitric oxide range, which corresponds to temperatures of the order of $4{,}000^\circ$ to $5{,}000^\circ$ K and the higher densities. Even though extensive nitric oxide formation leads to rather large errors in the ν_i, the approximate expressions given later for the thermodynamic functions remain fairly accurate because the properties of NO are comparable with those of N_2 and O_2. More accurate values for the ν_i can, of course, be obtained by solving the coupled algebraic equations (10a) and (10b) by iteration and using the values obtained for λ_1 and λ_2 in equations (36).

Explicit Expressions for Thermodynamic Properties

The compressibility factor Z of the gas mixture is given by equation (20) when the dissociation parameters ξ_1 and ξ_2 are replaced by their values as given in equations (64).

With the application of equations (52) and (63), the expression (26) for the internal energy of the gas mixture becomes

$$\frac{E}{RT} = \frac{5}{2} + \alpha \frac{\theta_3/T}{e^{\theta_3/T} - 1} + \beta \frac{\theta_4/T}{e^{\theta_4/T} - 1} + 2\alpha\xi_1\left(\sqrt{1 + \xi_1^2} - \xi_1\right)\left[\left(\frac{D_3}{k} + \frac{\theta_3}{2}\right)\frac{1}{T} - \frac{1}{2}\right] + 2\beta\xi_2\left(\sqrt{1 + \xi_2^2} - \xi_2\right)\left[\left(\frac{D_4}{k} + \frac{\theta_4}{2} + 2\bar{t}_2\right)\frac{1}{T} - \frac{1}{2}\right] \tag{65}$$

where, as before, ξ_1 and ξ_2 are given by equations (64). Similarly, equation (29) for the enthalpy H of the mixture takes the form

$$\frac{H}{RT} = \frac{7}{2} + \alpha \frac{\theta_3/T}{e^{\theta_3/T} - 1} + \beta \frac{\theta_4/T}{e^{\theta_4/T} - 1} +$$

$$2\alpha\xi_1\left(\sqrt{1 + \xi_1^2} - \xi_1\right)\left[\left(\frac{D_3}{k} + \frac{\theta_3}{2}\right)\frac{1}{T} + \frac{1}{2}\right] +$$

$$2\beta\xi_2\left(\sqrt{1 + \xi_2^2} - \xi_2\right)\left[\left(\frac{D_4}{k} + \frac{\theta_4}{2} + 2\bar{t}_2\right)\frac{1}{T} + \frac{1}{2}\right] \tag{66}$$

The corresponding expression for the work function (Helmholtz free energy) A follows from equation (31) and equations (51); thus,

$$-\frac{A}{RT} = 1 + \ln\frac{\rho_0}{\rho} + \frac{5}{2}\ln T +$$

$$\alpha \ln\left[\frac{1}{\alpha}\frac{\left(2\pi m_3 k\right)^{3/2} v_0}{2h^3(hc/k)(B_0)_3}\frac{1}{1 - e^{-\theta_3/T}}\right] +$$

$$\beta \ln\left[\frac{1}{\beta}\frac{3\left(2\pi m_4 k\right)^{3/2} v_0}{2h^3(hc/k)(B_0)_4}\frac{1}{1 - e^{-\theta_4/T}}\right] +$$

$$2\alpha\xi_1\left(\sqrt{1 + \xi_1^2} - \xi_1\right) - 2\alpha \ln\left(\sqrt{1 + \xi_1^2} - \xi_1\right) +$$

$$2\beta\xi_2\left(\sqrt{1 + \xi_2^2} - \xi_2\right) - 2\beta \ln\left(\sqrt{1 + \xi_2^2} - \xi_2\right) \tag{67}$$

Finally, the expression for the entropy S of the gas mixture follows from equations (33), (51), and (52) or from equations (32), (65), and (67); the resulting equation is

$$\frac{S}{R} = \frac{7}{2} + \ln \frac{\rho_0}{\rho} + \frac{5}{2} \ln T +$$

$$\alpha \left\{ \frac{\theta_3/T}{e^{\theta_3/T} - 1} + \ln \left[\frac{1}{\alpha} \frac{\left(2\pi m_3 k\right)^{3/2} v_0}{2h^3 (hc/k)(B_0)_3} \frac{1}{1 - e^{-\theta_3/T}} \right] \right\} +$$

$$\beta \left\{ \frac{\theta_4/T}{e^{\theta_4/T} - 1} + \ln \left[\frac{1}{\beta} \frac{3\left(2\pi m_4 k\right)^{3/2} v_0}{2h^3 (hc/k)(B_0)_4} \frac{1}{1 - e^{-\theta_4/T}} \right] \right\} +$$

$$2\alpha \left\{ \xi_1 \left(\sqrt{1 + \xi_1^2} - \xi_1 \right) \left[\left(\frac{D_3}{k} + \frac{\theta_3}{2} \right) \frac{1}{T} + \frac{1}{2} \right] - \ln \left(\sqrt{1 + \xi_1^2} - \xi_1 \right) \right\} +$$

$$2\beta \left\{ \xi_2 \left(\sqrt{1 + \xi_2^2} - \xi_2 \right) \left[\left(\frac{D_4}{k} + \frac{\theta_4}{2} + 2\bar{t}_2 \right) \frac{1}{T} + \frac{1}{2} \right] - \ln \left(\sqrt{1 + \xi_2^2} - \xi_2 \right) \right\} \tag{68}$$

As in the previous expressions, the dissociation parameters ξ_1 and ξ_2 are given by equations (64).

The density ρ_0 of the gas mixture at the selected standard conditions of temperature and pressure (273° K at 1 atmosphere) depends upon the ratio $\frac{\alpha}{\beta} = \frac{\alpha}{(1 - \alpha)}$ in accordance with equation (43); that is,

$$\rho_0 = \frac{\alpha m_3 + \beta m_4}{v_0} \tag{69}$$

Furthermore, equations (15) and (69) yield the additional expression

$$R = \frac{k}{\rho_0 v_0} \tag{70}$$

for the gas constant of the mixture.

The evaluation of the speed of sound, the isentropic exponent, and the specific heats is discussed in appendix A.

Numerical values of the physical constants which are needed to evaluate the preceding equations are given in appendix B.

Tables of Composition and Thermodynamic Properties of Nitrogen-Oxygen Mixtures

The principal advantage of the preceding analysis is that the composition and thermodynamic properties of the gas mixture are expressed analytically rather than in tabular form alone. Nevertheless, it is useful in many instances to have tables available as well. Except for pure nitrogen, air, and pure oxygen, tables for nitrogen-oxygen mixtures apparently are not available.

Since equations (37) become rather inaccurate when temperature and density favor the formation of a considerable amount of nitric oxide in the mixture, a more accurate composition calculation has been performed by utilizing a high-speed, digital computer. In this calculation, equations (62) were used for evaluating the temperature functions τ_i. The coupled algebraic equations (10) were solved for λ_1 and λ_2 by means of an iteration procedure which had been developed previously to provide uniform convergence. Equations (36) were then employed to evaluate the ν_i. The results are presented in tables I to V. The corresponding values of the compressibility factor, that is,

$$Z = \sum_i \nu_i \tag{71}$$

are given in table VI. Included in these tables, for comparison in the case where $\alpha = 0.78847$, are corresponding values from reference 2 and values derived from unpublished tables of equilibrium compositions of argon-free air by Joseph Hilsenrath of the National Bureau of Standards. The latter tables give Z and the mole fractions X_i directly; these values and the relations

$$\nu_i = ZX_i \tag{72}$$

yield the corresponding ν_i values.

The values of the ν_i, obtained by the iteration procedure mentioned previously and presented in tables I to V, can be used in evaluating

$\frac{E}{RT}$, $\frac{H}{RT}$, $\frac{S}{R}$, and so forth. However, for most purposes, the analytic expressions for the latter ratios, which were obtained previously while neglecting nitric oxide, are sufficiently accurate. Accordingly, equations (20), (66), and (68) have been used to obtain the values of Z, $\frac{H}{RT}$, and $\frac{S}{R}$ given in tables VII to IX. To permit comparison with more accurate calculations in the case where $\alpha = 0.78847$, values of Z, $\frac{H}{RT}$, and $\frac{S}{R}$ taken from reference 2 are included in tables VII to IX, respectively.

L
1
7
9

Appreciable errors will be noticed in all the tables at those (higher) temperatures and (lower) densities where ionization begins to affect the values. In tables VII to IX noticeable errors resulting from nitric oxide formation are found at temperatures of the order of 3,000° K to 6,500° K and at the higher densities.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., January 20, 1959.

APPENDIX A

SPEED OF SOUND, ISENTROPIC EXPONENT, AND SPECIFIC HEATS

The low-frequency speed of sound a in the gas mixture is given by the well-known equation

$$a^2 = \left(\frac{\partial p}{\partial \rho}\right)_S \tag{A1}$$

L
1
7
9

and the isentropic exponent is

$$\left(\frac{\partial \ln p}{\partial \ln \rho}\right)_S = \frac{\rho}{p}\left(\frac{\partial p}{\partial \rho}\right)_S = \frac{1}{RTZ}\left(\frac{\partial p}{\partial \rho}\right)_S \tag{A2}$$

Consequently, since the independent variables in the foregoing development are temperature and density, the following general relation, which can be derived from thermodynamics, is of interest:

$$\left(\frac{\partial p}{\partial \rho}\right)_S = \left(\frac{\partial p}{\partial \rho}\right)_T + \frac{\frac{p}{\rho^2} - \left(\frac{\partial E}{\partial \rho}\right)_T}{\left(\frac{\partial E}{\partial T}\right)_\rho}\left(\frac{\partial p}{\partial T}\right)_\rho \tag{A3}$$

With the aid of the thermodynamic relation

$$\left(\frac{\partial E}{\partial \rho}\right)_T = -\frac{RT^2}{\rho}\left(\frac{\partial Z}{\partial T}\right)_\rho \tag{A4}$$

equation (A3) can be put into a form which is more useful for present purposes; namely,

$$\frac{1}{RT}\left(\frac{\partial p}{\partial \rho}\right)_S = Z + \frac{\rho}{\rho_0}\left[\frac{\partial Z}{\partial\left(\rho/\rho_0\right)}\right]_T + \frac{\left[Z + T\left(\frac{\partial Z}{\partial T}\right)_\rho\right]^2}{\frac{E}{RT} + T\left[\frac{\partial(E/RT)}{\partial T}\right]_\rho} \tag{A5}$$

where R and Z are defined in equations (15) and (16).

The specific heats (per unit mass) at constant volume and pressure, respectively, are defined by

$$c_v = \left(\frac{\partial E}{\partial T}\right)_\rho \tag{A6a}$$

$$c_p = \left(\frac{\partial H}{\partial T}\right)_p \tag{A6b}$$

L
1
7
9

Equation (A6b), in terms of ρ and T as independent variables, can be expressed in the form

$$c_p = \left(\frac{\partial H}{\partial T}\right)_\rho - \frac{\left(\frac{\partial p}{\partial T}\right)_\rho}{\left(\frac{\partial p}{\partial \rho}\right)_T}\left(\frac{\partial H}{\partial \rho}\right)_T \tag{A7}$$

Thus, the following convenient thermodynamic expressions for the specific heats can be derived:

$$\frac{c_v}{R} = \frac{E}{RT} + T\left[\frac{\partial(E/RT)}{\partial T}\right]_\rho \tag{A8}$$

$$\frac{c_p}{R} = \frac{c_v}{R} + \frac{\left[Z + T\left(\frac{\partial Z}{\partial T}\right)_\rho\right]^2}{Z + \frac{\rho}{\rho_0}\left[\frac{\partial Z}{\partial(\rho/\rho_0)}\right]_T} \tag{A9}$$

The right-hand side of each of the thermodynamic equations (A5), (A8), and (A9) can be evaluated approximately in terms of the temperature and density by means of equations (20) and (26) or the equivalent equations (18) and (25). Equations (18) and (25), together with equations (14), (16), (19), (22), (24), (52), and (63) have been used in the derivation of the following approximate expressions for the three binomials which occur on the right-hand sides of equations (A5), (A8), and (A9).

$$Z + \frac{\rho}{\rho_0}\left[\frac{\partial Z}{\partial(\rho/\rho_0)}\right]_T = 1 + \alpha\frac{\xi_1}{\sqrt{1 + \xi_1^2}} + \beta\frac{\xi_2}{\sqrt{1 + \xi_2^2}} \tag{A10}$$

$$Z + T\left(\frac{\partial Z}{\partial T}\right)_\rho = 1 - 2\alpha\xi_1^2\left[\left(\frac{D_3}{k} + \frac{\theta_3}{2}\right)\frac{1}{T} + \frac{1}{2}\right] - 2\beta\xi_2^2\left[\left(\frac{D_4}{k} + \frac{\theta_4}{2} + 2\bar{t}_2\right)\frac{1}{T} + \frac{1}{2}\right] +$$

$$\alpha\frac{\xi_1}{\sqrt{1 + \xi_1^2}}\left[\frac{3}{2} + \xi_1^2 + \left(1 + 2\xi_1^2\right)\left(\frac{D_3}{k} + \frac{\theta_3}{2}\right)\frac{1}{T}\right] +$$

$$\beta\frac{\xi_2}{\sqrt{1 + \xi_2^2}}\left[\frac{3}{2} + \xi_2^2 + \left(1 + 2\xi_2^2\right)\left(\frac{D_4}{k} + \frac{\theta_4}{2} + 2\bar{t}_2\right)\frac{1}{T}\right] \tag{A11}$$

L
1
7
9

$$\frac{E}{RT} + T\left[\frac{\partial(E/RT)}{\partial T}\right]_\rho = \frac{5}{2} + \alpha\frac{\left(\frac{\theta_3}{T}\right)^2 e^{\theta_3/T}}{\left(e^{\theta_3/T} - 1\right)^2} + \beta\frac{\left(\frac{\theta_4}{T}\right)^2 e^{\theta_4/T}}{\left(e^{\theta_4/T} - 1\right)^2} +$$

$$\alpha\xi_1\left(\frac{1 + 2\xi_1^2}{\sqrt{1 + \xi_1^2}} - 2\xi_1\right)\left[\left(\frac{D_3}{k} + \frac{\theta_3}{2}\right)\frac{1}{T} - \frac{1}{2}\right]^2 +$$

$$\beta\xi_2\left(\frac{1 + 2\xi_2^2}{\sqrt{1 + \xi_2^2}} - 2\xi_2\right)\left[\left(\frac{D_4}{k} + \frac{\theta_4}{2} + 2\bar{t}_2\right)\frac{1}{T} - \frac{1}{2}\right]^2 -$$

$$\alpha\xi_1\left(\sqrt{1 + \xi_1^2} - \xi_1\right) - \beta\xi_2\left(\sqrt{1 + \xi_2^2} - \xi_2\right) \tag{A12}$$

For a dissociating mixture of nitrogen and oxygen, therefore, equation (A5) and the approximate expressions (20), (64), (A10), (A11), and (A12) can be used to calculate the low-frequency speed of sound, the isentropic exponent, and the specific heats in equations (A1), (A2), (A8), and (A9).

APPENDIX B

PHYSICAL CONSTANTS

Wherever possible, the physical constants which follow are those of references 12 and 13. Except for the dissociation energies, which correspond to those used in reference 2, the molecular constants have been derived from reference 11.

$$k = 1.38044 \times 10^{-16} \text{ erg deg}^{-1}$$

$$h = 6.62517 \times 10^{-27} \text{ erg sec}$$

$$\frac{hc}{k} = 1.43880 \text{ cm deg}$$

$$N_{ch} = \text{Avogadro number (chemical scale)}$$

$$= 6.02322 \times 10^{23} \text{ (gram mole)}^{-1}$$

$$m_1 = 2.3257 \times 10^{-23} \text{ gram}$$

$$m_2 = 2.6564 \times 10^{-23} \text{ gram}$$

$$m_3 = 4.6513 \times 10^{-23} \text{ gram}$$

$$m_4 = 5.3128 \times 10^{-23} \text{ gram}$$

$$m_5 = 4.9821 \times 10^{-23} \text{ gram}$$

$$v_0 = 3.7193 \times 10^{-20} \text{ cm}^3 \text{ (273}^\circ \text{ K at 1 atmosphere)}$$

$$(B_0)_3 = 2.0006 \text{ cm}^{-1}$$

$$(B_0)_4 = 1.4378 \text{ cm}^{-1}$$

$$(B_0)_5 = 1.6957 \text{ cm}^{-1}$$

$$\theta_3 = 3353.4 \text{ deg}$$

$$\theta_4 = 2239.3 \text{ deg}$$

$$\theta_5 = 2699.1 \text{ deg}$$

$$\frac{D_3}{k} = 1.133 \times 10^5 \text{ deg}$$

$$\frac{D_4}{k} = 5.937 \times 10^4 \text{ deg}$$

$$\frac{D_5}{k} = 7.552 \times 10^4 \text{ deg}$$

$$t_{12} = 228.05 \text{ deg}$$

$$t_{22} = 325.89 \text{ deg}$$

$$\bar{t}_2 = 112.23 \text{ deg}$$

$$t_{15} = 174.24 \text{ deg}$$

$$\bar{t}_5 = 87.12 \text{ deg}$$

REFERENCES

1. Gilmore, F. R.: Equilibrium Composition and Thermodynamic Properties of Air to 24,000° K. U. S. Air Force Project RAND Res. Memo. RM-1543, The RAND Corp., Aug. 24, 1955. (Also available from ASTIA as AD 84052.)

2. Hilsenrath, Joseph, and Beckett, Charles W.: Tables of Thermodynamic Properties of Argon-Free Air to 15,000° K. AEDC-TN-56-12, Arnold Eng. Dev. Center, Sept. 1956. (Also available from ASTIA as Doc. No. AD 98974.)

3. Logan, J. G., Jr., and Treanor, C. E.: Tables of Thermodynamic Properties of Air from 3,000° K to 10,000° K at Intervals of 100° K. Rep. No. BE-1007-A-3, Cornell Aero. Lab., Inc., Jan. 1957.

4. Greifinger, P. S.: Transport Coefficients of Dissociating and Slightly Ionizing Air. U. S. Air Force Project RAND Res. Memo. RM-1794 (ASTIA Doc. No. AD 133002), The RAND Corp., Apr. 9, 1957.

5. Hansen, C. Frederick: Approximations for the Thermodynamic and Transport Properties of High-Temperature Air. NACA TN 4150, 1958.

6. Hirschfelder, Joseph O.: Heat Transfer in Chemically Reacting Mixtures. I. Jour. Chem. Phys., vol. 26, no. 2, Feb. 1957, pp. 274-281.

7. Butler, James N., and Brokaw, Richard S.: Thermal Conductivity of Gas Mixtures in Chemical Equilibrium. Jour. Chem. Phys., vol. 26, no. 6, June 1957, pp. 1636-1643.

8. Meyerott, Ronald E.: Radiation Heat Transfer to Hypersonic Vehicles. Presented to Third Combustion and Propulsion Panel Colloquium of AGARD (Palermo, Sicily), Mar. 17-21, 1958.

9. Herzfeld, Karl F.: Relaxation Phenomena in Gases. Section H, vol. I (Thermodynamics and Physics of Matter), High Speed Aerodynamics and Jet Propulsion, Princeton, 1955.

10. Fowler, R. H., and Guggenheim, E. A.: Statistical Thermodynamics. The Macmillan Co., 1939.

11. Herzberg, Gerhard: Molecular Spectra and Molecular Structure. I. Spectra of Diatomic Molecules. Second ed., D. Van Nostrand Co., Inc., c.1950.

12. Moore, Charlotte E.: Atomic Energy Levels. Vol. I - 1H—23V. Cir. 467, Nat. Bur. Standards, June 15, 1949.

13. Cohen, E. Richard, DuMond, Jesse W. M., Layton, Thomas W., and Rollett, John S.: Analysis of Variance of the 1952 Data on the Atomic Constants and a New Adjustment, 1955. Rev. Modern Phys., vol. 27, no. 4, Oct. 1955, pp. 363-380.

L
1
7
9

TABLE I.- CONCENTRATION ν_1 OF ATOMIC NITROGEN (N)

[For dependence of ρ_0 on α, see equation (69) or table VII.]

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	α = 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From unpublished tables)
1,500	-6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
1,500	-5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
1,500	-4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
1,500	-3	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
1,500	-2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
1,500	-1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
1,500	0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
1,500	1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
2,000	-6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
2,000	-5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
2,000	-4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
2,000	-3	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
2,000	-2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
2,000	-1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
2,000	0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
2,000	1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
2,500	-6	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
2,500	-5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
2,500	-4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
2,500	-3	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
2,500	-2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
2,500	-1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
2,500	0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
2,500	1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
3,000	-6	0.0000	0.0013	0.0018	0.0022	0.0026	0.0029	0.0031	0.0034	0.0036	0.0039	0.0041	0.0036	0.00371
3,000	-5	.0000	.0004	.0006	.0007	.0008	.0009	.0010	.0011	.0011	.0012	.0013	.0011	.00117
3,000	-4	.0000	.0001	.0002	.0002	.0003	.0003	.0003	.0003	.0004	.0004	.0004	.0004	.00037
3,000	-3	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.00011
3,000	-2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00003
3,000	-1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00001
3,000	0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
3,000	1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
3,500	-6	0.0000	0.0182	0.0261	0.0322	0.0375	0.0418	0.0453	0.0487	0.0532	0.0565	0.0596	0.0528	
3,500	-5	.0000	.0059	.0084	.0104	.0120	.0134	.0147	.0159	.0170	.0181	.0190	.0169	
3,500	-4	.0000	.0019	.0027	.0033	.0038	.0042	.0047	.0050	.0054	.0057	.0060	.0054	
3,500	-3	.0000	.0006	.0008	.0010	.0012	.0013	.0015	.0016	.0017	.0018	.0019	.0017	
3,500	-2	.0000	.0002	.0003	.0003	.0004	.0004	.0005	.0005	.0005	.0006	.0006	.0005	
3,500	-1	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0002	.0002	.0002	.0002	
3,500	0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	
3,500	1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
4,000	-6	0.0000	0.1012	0.1583	0.2030	0.2409	0.2745	0.3049	0.3330	0.3591	0.3837	0.4069	0.3562	0.36024
4,000	-5	.0000	.0406	.0594	.0738	.0860	.0968	.1065	.1155	.1238	.1317	.1391	.1229	.12445
4,000	-4	.0000	.0138	.0197	.0243	.0282	.0316	.0347	.0376	.0402	.0427	.0451	.0399	.04045
4,000	-3	.0000	.0044	.0063	.0077	.0090	.0101	.0110	.0120	.0128	.0136	.0144	.0127	.01287
4,000	-2	.0000	.0013	.0019	.0024	.0028	.0031	.0035	.0038	.0040	.0043	.0046	.0040	.00406
4,000	-1	.0000	.0004	.0006	.0007	.0009	.0010	.0011	.0012	.0013	.0014	.0014	.0013	.00127
4,000	0	.0000	.0001	.0002	.0002	.0003	.0003	.0003	.0004	.0004	.0004	.0005	.0004	.00040
4,000	1	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.00012
4,500	-6	0.0000	0.1855	0.3489	0.4966	0.6324	0.7588	0.8775	0.9898	1.0966	1.1986	1.2965	1.0845	
4,500	-5	.0000	.1294	.2117	.2773	.3335	.3835	.4290	.4710	.5102	.5471	.5820	.5058	
4,500	-4	.0000	.0578	.0862	.1081	.1265	.1429	.1576	.1712	.1838	.1957	.2070	.1824	
4,500	-3	.0000	.0203	.0294	.0364	.0423	.0475	.0522	.0565	.0605	.0643	.0679	.0601	
4,500	-2	.0000	.0064	.0093	.0115	.0134	.0151	.0166	.0180	.0193	.0206	.0217	.0192	
4,500	-1	.0000	.0019	.0028	.0035	.0041	.0047	.0052	.0057	.0061	.0065	.0069	.0060	
4,500	0	.0000	.0005	.0008	.0011	.0013	.0014	.0016	.0018	.0019	.0020	.0022	.0019	
4,500	1	.0000	.0002	.0003	.0003	.0004	.0004	.0005	.0005	.0006	.0006	.0007	.0006	

TABLE I.- CONCENTRATION ν_1 OF ATOMIC NITROGEN (N) - Concluded

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	α												
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From unpublished tables)
5,000	-6	0.0000	0.1986	0.3946	0.5881	0.7792	0.9679	1.1543	1.3386	1.5207	1.7008	1.8790	1.4998	1.50058
5,000	-5	.0000	.1878	.3563	.5104	.6534	.7872	.9136	1.0336	1.1480	1.2577	1.3631	1.1351	1.14006
5,000	-4	.0000	.1358	.2250	.2967	.3583	.4132	.4632	.5094	.5526	.5932	.6318	.5477	.55219
5,000	-3	.0000	.0623	.0936	.1178	.1383	.1563	.1727	.1877	.2017	.2149	.2274	.2002	.20211
5,000	-2	.0000	.0218	.0319	.0396	.0462	.0520	.0573	.0621	.0667	.0709	.0749	.0662	.06681
5,000	-1	.0000	.0066	.0099	.0124	.0145	.0164	.0182	.0198	.0213	.0227	.0240	.0211	.02129
5,000	0	.0000	.0019	.0029	.0037	.0044	.0050	.0056	.0061	.0067	.0071	.0076	.0066	.00667
5,000	1	.0000	.0006	.0009	.0011	.0013	.0015	.0017	.0019	.0021	.0022	.0024	.0021	.00208
5,500	-6	0.0000	0.1998	0.3993	0.5984	0.7972	0.9956	1.1937	1.3914	1.5888	1.7858	1.9825	1.5660	
5,500	-5	.0000	.1982	.3931	.5847	.7733	.9590	1.1419	1.3222	1.4999	1.6752	1.8482	1.4796	
5,500	-4	.0000	.1845	.3462	.4918	.6254	.7495	.8660	.9760	1.0806	1.1804	1.2762	1.0688	
5,500	-3	.0000	.1265	.2067	.2706	.3254	.3741	.4184	.4594	.4976	.5336	.5677	.4933	
5,500	-2	.0000	.0591	.0827	.1040	.1221	.1381	.1526	.1659	.1784	.1901	.2012	.1770	
5,500	-1	.0000	.0183	.0273	.0342	.0401	.0453	.0500	.0544	.0585	.0623	.0660	.0580	
5,500	0	.0000	.0053	.0081	.0104	.0123	.0140	.0156	.0171	.0185	.0198	.0211	.0183	
5,500	1	.0000	.0015	.0024	.0031	.0037	.0043	.0048	.0053	.0058	.0062	.0067	.0057	
6,000	-6	0.0000	0.2000	0.3999	0.5997	0.7995	0.9992	1.1988	1.3984	1.5979	1.7974	1.9968	1.5749	1.56350
6,000	-5	.0000	.1997	.3987	.5971	.7948	.9920	1.1885	1.3844	1.5797	1.7744	1.9685	1.5572	1.55412
6,000	-4	.0000	.1967	.3876	.5730	.7535	.9294	1.1011	1.2688	1.4329	1.5934	1.7508	1.4141	1.41716
6,000	-3	.0000	.1743	.3167	.4403	.5510	.6521	.7458	.8335	.9162	.9948	1.0697	.9069	.91518
6,000	-2	.0000	.1046	.1663	.2148	.2562	.2929	.3262	.3569	.3856	.4127	.4383	.3824	.38757
6,000	-1	.0000	.0408	.0614	.0774	.0910	.1031	.1140	.1241	.1335	.1424	.1508	.1325	.13442
6,000	0	.0000	.0124	.0190	.0243	.0288	.0328	.0365	.0399	.0431	.0461	.0490	.0427	.04334
6,000	1	.0000	.0034	.0055	.0072	.0086	.0100	.0112	.0124	.0135	.0146	.0156	.0134	.01356
6,500	-5	0.0000	0.1999	0.3997	0.5993	0.7988	0.9981	1.1972	1.3962	1.5951	1.7938	1.9923	1.5721	
6,500	-4	.0000	.1992	.3969	.5931	.7878	.9812	1.1732	1.3638	1.5532	1.7412	1.9280	1.5314	
6,500	-3	.0000	.1924	.3724	.5421	.7031	.8567	1.0037	1.1450	1.2812	1.4128	1.5402	1.2658	
6,500	-2	.0000	.1518	.2618	.3526	.4318	.5030	.5683	.6288	.6856	.7392	.7901	.6792	
6,500	-1	.0000	.0747	.1159	.1482	.1756	.1999	.2220	.2424	.2615	.2795	.2965	.2594	
6,500	0	.0000	.0251	.0386	.0493	.0584	.0665	.0739	.0807	.0872	.0933	.0990	.0864	
6,500	1	.0000	.0069	.0112	.0147	.0177	.0204	.0230	.0253	.0276	.0298	.0319	.0273	
7,000	-4	0.0000	0.1998	0.3991	0.5973	0.7963	0.9943	1.1919	1.3890	1.5857	1.7819	1.9778	1.5630	1.55414
7,000	-3	.0000	.1976	.3909	.5804	.7661	.9483	1.1272	1.3030	1.4758	1.6458	1.8131	1.4561	1.45953
7,000	-2	.0000	.1797	.3336	.4704	.5948	.7096	.8169	.9179	1.0136	1.1048	1.1921	1.0028	1.01884
7,000	-1	.0000	.1141	.1861	.2435	.2927	.3366	.3766	.4136	.4481	.4807	.5117	.4443	.45581
7,000	0	.0000	.0444	.0691	.0885	.1051	.1198	.1333	.1458	.1574	.1685	.1790	.1561	.16072
7,000	1	.0000	.0127	.0206	.0270	.0326	.0376	.0423	.0466	.0507	.0547	.0584	.0503	.05178
8,000	-3	0.0000	0.1996	0.3987	0.5971	0.7949	0.9922	1.1888	1.3849	1.5804	1.7754	1.9697	1.5579	1.54453
8,000	-2	.0000	.1964	.3873	.5731	.7542	.9309	1.1036	1.2725	1.4379	1.5999	1.7588	1.4190	1.42821
8,000	-1	.0000	.1720	.3148	.4336	.5520	.6551	.7509	.8408	.9258	1.0066	1.0838	.9162	.94471
8,000	0	.0000	.0980	.1604	.2104	.2534	.2919	.3270	.3596	.3901	.4189	.4463	.3867	.40480
8,000	1	.0000	.0334	.0545	.0715	.0862	.0995	.1117	.1231	.1339	.1441	.1539	.1327	.13959
9,000	-2	0.0000	0.1991	0.3970	0.5936	0.7890	0.9832	1.1763	1.3682	1.5589	1.7486	1.9371	1.5370	1.52625
9,000	-1	.0000	.1918	.3732	.5457	.7105	.8686	1.0208	1.1676	1.3097	1.4474	1.5812	1.2935	1.32109
9,000	0	.0000	.1481	.2617	.3576	.4424	.5193	.5902	.6564	.7187	.7778	.8342	.7117	.75368
9,000	1	.0000	.0658	.1094	.1449	.1758	.2036	.2292	.2530	.2754	.2967	.3170	.2729	.29397
10,000	-1	0.0000	0.1972	0.3909	0.5813	0.7685	0.9529	1.1343	1.3131	1.4893	1.6630	1.8344	1.4691	1.47570
10,000	0	.0000	.1765	.3321	.4730	.6028	.7238	.8377	.9456	1.0484	1.1469	1.2414	1.0368	1.09546
10,000	1	.0000	.1029	.1773	.2391	.2934	.3426	.3878	.4301	.4699	.5078	.5439	.4655	.51199

L-179

TABLE II.- CONCENTRATION ν_2 OF ATOMIC OXYGEN (O)

T, °K	$\log_{10} \frac{p}{p_0}$	α												
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From unpublished tables)
1,500	-6	0.0016	0.0016	0.0015	0.0014	0.0013	0.0012	0.0010	0.0009	0.0007	0.0005	0.0000	0.0008	
1,500	-5	.0005	.0005	.0005	.0004	.0004	.0004	.0003	.0003	.0002	.0002	.0000	.0002	
1,500	-4	.0002	.0002	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0000	.0001	
1,500	-3	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
1,500	-2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
1,500	-1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
1,500	0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
1,500	1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
2,000	-6	0.2266	0.2140	0.2008	0.1868	0.1718	0.1556	0.1376	0.1173	0.0932	0.0621	0.0000	0.0962	0.09817
2,000	-5	.0747	.0707	.0665	.0620	.0573	.0521	.0464	.0400	.0323	.0223	.0000	.0333	.03401
2,000	-4	.0239	.0227	.0213	.0199	.0184	.0168	.0150	.0129	.0105	.0074	.0000	.0108	.01106
2,000	-3	.0076	.0072	.0068	.0063	.0059	.0053	.0048	.0041	.0034	.0024	.0000	.0035	.00354
2,000	-2	.0024	.0023	.0021	.0020	.0019	.0017	.0015	.0013	.0011	.0007	.0000	.0011	.00112
2,000	-1	.0008	.0007	.0007	.0006	.0006	.0005	.0005	.0004	.0003	.0002	.0000	.0003	.00035
2,000	0	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0001	.0001	.0001	.0000	.0001	.00011
2,000	1	.0001	.0001	.0001	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.00004
2,500	-6	1.7326	1.5734	1.4141	1.2519	1.0864	0.9170	0.7436	0.5656	0.3827	0.1943	0.0000	0.4041	
2,500	-5	1.0387	.9627	.8857	.8052	.7202	.6295	.5319	.4251	.3059	.1684	.0000	.3204	
2,500	-4	.4210	.3950	.3687	.3410	.3115	.2795	.2444	.2049	.1585	.0997	.0000	.1644	
2,500	-3	.1443	.1360	.1276	.1187	.1093	.0990	.0877	.0750	.0599	.0403	.0000	.0618	
2,500	-2	.0468	.0442	.0415	.0387	.0357	.0325	.0289	.0248	.0200	.0138	.0000	.0206	
2,500	-1	.0149	.0141	.0132	.0124	.0114	.0104	.0093	.0080	.0065	.0045	.0000	.0066	
2,500	0	.0047	.0045	.0042	.0039	.0036	.0033	.0029	.0025	.0021	.0014	.0000	.0021	
2,500	1	.0015	.0014	.0013	.0012	.0011	.0010	.0009	.0008	.0007	.0005	.0000	.0007	
3,000	-6	1.9932	1.7925	1.5931	1.3940	1.1949	0.9958	0.7967	0.5976	0.3985	0.1993	0.0000	0.4214	0.42135
3,000	-5	1.9361	1.7422	1.5512	1.3601	1.1684	.9760	.7827	.5886	.3934	.1972	.0000	.4159	.41574
3,000	-4	1.5764	1.4340	1.2943	1.1518	1.0053	.8543	.6979	.5353	.3656	.1877	.0000	.3856	.38488
3,000	-3	.8289	.7683	.7090	.6472	.5821	.5124	.4370	.3537	.2594	.1473	.0000	.2710	.26966
3,000	-2	.3145	.2942	.2745	.2539	.2320	.2084	.1826	.1535	.1194	.0760	.0000	.1237	.12277
3,000	-1	.1054	.0989	.0927	.0861	.0791	.0716	.0633	.0539	.0429	.0287	.0000	.0443	.04397
3,000	0	.0340	.0319	.0299	.0278	.0256	.0232	.0206	.0176	.0142	.0096	.0000	.0146	.01446
3,000	1	.0108	.0102	.0095	.0089	.0082	.0074	.0066	.0056	.0045	.0031	.0000	.0047	.00463
3,500	-6	1.9996	1.7989	1.5987	1.5987	1.1988	0.9989	0.7990	0.5992	0.3995	0.1997	0.0000	0.4225	
3,500	-5	1.9959	1.7941	1.5941	1.3945	1.1951	.9957	.7965	.5973	.3982	.1991	.0000	.4211	
3,500	-4	1.9607	1.7603	1.5648	1.3699	1.1750	.9801	.7848	.5892	.3933	.1969	.0000	.4159	
3,500	-3	1.7034	1.5372	1.3782	1.2181	1.0556	.8902	.7211	.5481	.3706	.1881	.0000	.3913	
3,500	-2	.9928	.9119	.8354	.7567	.6746	.5877	.4947	.3938	.2820	.1543	.0000	.2956	
3,500	-1	.3961	.3681	.3417	.3144	.2857	.2550	.2215	.1840	.1406	.0863	.0000	.1460	
3,500	0	.1351	.1260	.1175	.1088	.0996	.0896	.0788	.0666	.0524	.0341	.0000	.0542	
3,500	1	.0438	.0409	.0382	.0354	.0325	.0293	.0259	.0220	.0175	.0116	.0000	.0180	
4,000	-6	1.9999	1.7997	1.5995	1.3995	1.1995	0.9995	0.7996	0.5997	0.3998	0.1999	0.0000	0.4228	0.42274
4,000	-5	1.9995	1.7984	1.5981	1.3980	1.1981	.9983	.7985	.5988	.3992	.1996	.0000	.4222	.42208
4,000	-4	1.9950	1.7919	1.5916	1.3919	1.1926	.9935	.7946	.5958	.3971	.1985	.0000	.4200	.41988
4,000	-3	1.9524	1.7490	1.5536	1.3594	1.1656	.9719	.7781	.5841	.3898	.1951	.0000	.4122	.41172
4,000	-2	1.6569	1.4899	1.3346	1.1792	1.0219	.8619	.6986	.5313	.3596	.1827	.0000	.3796	.37782
4,000	-1	.9268	.8475	.7748	.7008	.6240	.5431	.4569	.3636	.2603	.1424	.0000	.2728	.26860
4,000	0	.3621	.3347	.3096	.2841	.2574	.2290	.1981	.1639	.1243	.0754	.0000	.1293	.12594
4,000	1	.1226	.1137	.1057	.0975	.0889	.0797	.0697	.0586	.0456	.0291	.0000	.0472	.04574
4,500	-6	2.0000	1.7999	1.5999	1.3998	1.1998	0.9998	0.7999	0.5999	0.3999	0.1999	0.0000	0.4230	
4,500	-5	1.9999	1.7994	1.5992	1.3991	1.1991	.9992	.7993	.5994	.3996	.1998	.0000	.4226	
4,500	-4	1.9990	1.7970	1.5965	1.3964	1.1965	.9968	.7972	.5978	.3984	.1992	.0000	.4214	
4,500	-3	1.9903	1.7846	1.5841	1.3848	1.1861	.9878	.7898	.5921	.3946	.1972	.0000	.4174	
4,500	-2	1.9104	1.7058	1.5143	1.3250	1.1364	.9480	.7594	.5705	.3810	.1909	.0000	.4029	
4,500	-1	1.4698	1.3204	1.1856	1.0513	.9152	.7761	.6330	.4849	.3310	.1698	.0000	.3491	
4,500	0	.7217	.6590	.6028	.5461	.4876	.4260	.3604	.2889	.2093	.1167	.0000	.2190	
4,500	1	.2658	.2448	.2259	.2069	.1871	.1662	.1436	.1186	.0898	.0544	.0000	.0934	

TABLE II.- CONCENTRATION ν_2 OF ATOMIC OXYGEN (O) - Concluded

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	α												
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From unpublished tables)
5,000	-6	2.0000	1.8000	1.6000	1.4000	1.2000	1.0000	0.8000	0.6000	0.4000	0.2000	0.0000	0.4230	0.42266
5,000	-5	2.0000	1.7998	1.5998	1.3997	1.1997	.9997	.7997	.5997	.3998	.1999	.0000	.4229	.42259
5,000	-4	1.9997	1.7988	1.5984	1.3982	1.1982	.9983	.7985	.5988	.3991	.1995	.0000	.4221	.42186
5,000	-3	1.9973	1.7934	1.5923	1.3921	1.1925	.9931	.7941	.5953	.3967	.1983	.0000	.4196	.41930
5,000	-2	1.9739	1.7638	1.5637	1.3659	1.1692	.9734	.7781	.5832	.3886	.1942	.0000	.4111	.41045
5,000	-1	1.7859	1.5885	1.4108	1.2362	1.0626	.8887	.7140	.5381	.3607	.1814	.0000	.3812	.37914
5,000	0	1.1352	1.0221	.9222	.8231	.7224	.6186	.5106	.3968	.2757	.1447	.0000	.2901	.28453
5,000	1	.4765	.4349	.3980	.3613	.3235	.2838	.2415	.1953	.1433	.0818	.0000	.1497	.14409
5,500	-6	2.0000	1.8000	1.6000	1.4000	1.2000	1.0000	0.8000	0.6000	0.4000	0.2000	0.0000	0.4231	
5,500	-5	2.0000	1.8000	1.5999	1.3999	1.1999	.9999	.7999	.5999	.3999	.2000	.0000	.4230	
5,500	-4	1.9999	1.7996	1.5994	1.3992	1.1992	.9992	.7993	.5994	.3995	.1998	.0000	.4226	
5,500	-3	1.9991	1.7969	1.5960	1.3956	1.1956	.9959	.7964	.5971	.3979	.1989	.0000	.4209	
5,500	-2	1.9907	1.7824	1.5806	1.3807	1.1818	.9837	.7861	.5891	.3924	.1961	.0000	.4151	
5,500	-1	1.9145	1.7005	1.5047	1.3133	1.1239	.9357	.7482	.5611	.3741	.1871	.0000	.3957	
5,500	0	1.4852	1.3209	1.1775	1.0374	.8976	.7565	.6131	.4666	.3162	.1609	.0000	.3337	
5,500	1	.7359	.6653	.6031	.5418	.4794	.4148	.3469	.2743	.1950	.1057	.0000	.2045	
6,000	-6	2.0000	1.8000	1.6000	1.4000	1.2000	1.0000	0.8000	0.6000	0.4000	0.2000	0.0000	0.4231	0.41922
6,000	-5	2.0000	1.8000	1.6000	1.4000	1.2000	1.0000	.8000	.6000	.4000	.2000	.0000	.4230	.42174
6,000	-4	2.0000	1.7998	1.5998	1.3997	1.1997	.9997	.7997	.5997	.3998	.1999	.0000	.4229	.42222
6,000	-3	1.9996	1.7986	1.5980	1.3977	1.1976	.9977	.7979	.5983	.3988	.1993	.0000	.4218	.42102
6,000	-2	1.9961	1.7906	1.5886	1.3881	1.1884	.9893	.7907	.5925	.3947	.1972	.0000	.4175	.41690
6,000	-1	1.9626	1.7464	1.5448	1.3472	1.1518	.9578	.7649	.5728	.3814	.1905	.0000	.4035	.40223
6,000	0	1.7144	1.5141	1.3396	1.1709	1.0045	.8389	.6732	.5069	.3395	.1707	.0000	.3589	.35502
6,000	1	1.0096	.9036	.8110	.7208	.6303	.5379	.4425	.3428	.2374	.1241	.0000	.2499	.24169
6,500	-5	2.0000	1.8000	1.6000	1.4000	1.2000	1.0000	0.8000	0.6000	0.4000	0.2000	0.0000	0.4231	
6,500	-4	2.0000	1.7999	1.5999	1.3999	1.1999	.9999	.7999	.5999	.3999	.2000	.0000	.4230	
6,500	-3	1.9998	1.7994	1.5991	1.3989	1.1988	.9988	.7989	.5991	.3993	.1996	.0000	.4224	
6,500	-2	1.9981	1.7949	1.5934	1.3927	1.1926	.9930	.7938	.5949	.3964	.1981	.0000	.4193	
6,500	-1	1.9818	1.7682	1.5649	1.3649	1.1669	.9702	.7747	.5800	.3861	.1928	.0000	.4084	
6,500	0	1.8424	1.6242	1.4323	1.2473	1.0658	.8864	.7082	.5308	.3538	.1769	.0000	.3742	
6,500	1	1.2613	1.1183	.9947	.8757	.7578	.6393	.5190	.3959	.2691	.1376	.0000	.2840	
7,000	-4	2.0000	1.8000	1.6000	1.3999	1.1999	0.9999	0.7999	0.6000	0.4000	0.2000	0.0000	0.4230	0.42039
7,000	-3	1.9999	1.7997	1.5996	1.3995	1.1994	.9994	.7995	.5995	.3997	.1998	.0000	.4227	.42160
7,000	-2	1.9990	1.7973	1.5965	1.3957	1.1955	.9956	.7960	.5967	.3976	.1987	.0000	.4206	.41965
7,000	-1	1.9902	1.7803	1.5767	1.3758	1.1765	.9784	.7813	.5850	.3894	.1945	.0000	.4120	.41078
7,000	0	1.9098	1.6860	1.4856	1.2920	1.1024	.9153	.7300	.5462	.3633	.1814	.0000	.3844	.38168
7,000	1	1.4675	1.2917	1.1408	.9969	.8560	.7160	.5759	.4349	.2923	.1476	.0000	.3089	.30163
8,000	-3	2.0000	1.7999	1.5999	1.3998	1.1998	0.9998	0.7998	0.5999	0.3999	0.1999	0.0000	0.4230	0.41943
8,000	-2	1.9996	1.7992	1.5988	1.3986	1.1984	.9984	.7985	.5988	.3991	.1995	.0000	.4221	.42058
8,000	-1	1.9964	1.7923	1.5898	1.3886	1.1884	.9889	.7901	.5918	.3941	.1968	.0000	.4169	.41550
8,000	0	1.9655	1.7457	1.5398	1.3394	1.1426	.9482	.7558	.5650	.3756	.1873	.0000	.3974	.39509
8,000	1	1.7319	1.5150	1.3280	1.1514	.9804	.8130	.6480	.4847	.3225	.1610	.0000	.3411	.33523
9,000	-2	1.9998	1.7997	1.5995	1.3994	1.1994	0.9994	0.7994	0.5995	0.3996	0.1998	0.0000	0.4227	0.41909
9,000	-1	1.9984	1.7967	1.5955	1.3948	1.1945	.9946	.7951	.5958	.3969	.1983	.0000	.4199	.41811
9,000	0	1.9839	1.7721	1.5664	1.3643	1.1648	.9672	.7713	.5768	.3835	.1913	.0000	.4058	.40360
9,000	1	1.8590	1.6299	1.4270	1.2347	1.0489	.8675	.6896	.5143	.3411	.1698	.0000	.3610	.35599
10,000	-1	1.9991	1.7984	1.5978	1.3975	1.1973	0.9973	0.7975	0.5979	0.3984	0.1991	0.0000	0.4214	0.41833
10,000	0	1.9913	1.7849	1.5810	1.3790	1.1786	.9796	.7817	.5850	.3891	.1942	.0000	.4117	.40953
10,000	1	1.9193	1.6923	1.4838	1.2845	1.0912	.9023	.7169	.5343	.3542	.1762	.0000	.3749	.37049

L-179

TABLE III.- CONCENTRATION ν_3 OF DIATOMIC NITROGEN (N_2)

T, °K	$\log_{10} \frac{p}{p_0}$	α												
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From unpublished tables)
1,500	-6	0.0000	0.0995	0.1994	0.2993	0.3992	0.4992	0.5992	0.6993	0.7994	0.8995	1.0000	0.7878	
1,500	-5	.0000	.0995	.1994	.2993	.3992	.4992	.5992	.6993	.7994	.8995	1.0000	.7878	
1,500	-4	.0000	.0995	.1994	.2993	.3992	.4992	.5992	.6993	.7994	.8995	1.0000	.7878	
1,500	-3	.0000	.0995	.1994	.2993	.3992	.4992	.5992	.6993	.7994	.8995	1.0000	.7878	
1,500	-2	.0000	.0995	.1994	.2993	.3992	.4992	.5992	.6993	.7994	.8995	1.0000	.7878	
1,500	-1	.0000	.0995	.1994	.2993	.3992	.4992	.5992	.6993	.7994	.8995	1.0000	.7878	
1,500	0	.0000	.0995	.1994	.2993	.3992	.4992	.5992	.6993	.7994	.8995	1.0000	.7878	
1,500	1	.0000	.0995	.1994	.2993	.3992	.4992	.5992	.6993	.7994	.8995	1.0000	.7878	
2,000	-6	0.0000	0.0973	0.1964	0.2958	0.3956	0.4955	0.5957	0.6960	0.7966	0.8976	1.0000	0.7850	0.78479
2,000	-5	.0000	.0971	.1962	.2956	.3953	.4952	.5954	.6957	.7963	.8973	1.0000	.7847	.78444
2,000	-4	.0000	.0971	.1961	.2956	.3953	.4952	.5953	.6956	.7962	.8971	1.0000	.7845	.78432
2,000	-3	.0000	.0971	.1961	.2955	.3952	.4951	.5952	.6955	.7961	.8971	1.0000	.7845	.78430
2,000	-2	.0000	.0971	.1961	.2955	.3952	.4951	.5952	.6955	.7961	.8971	1.0000	.7845	.78428
2,000	-1	.0000	.0971	.1961	.2955	.3952	.4951	.5952	.6955	.7961	.8971	1.0000	.7845	.78427
2,000	0	.0000	.0971	.1961	.2955	.3952	.4951	.5952	.6955	.7961	.8971	1.0000	.7845	.78425
2,000	1	.0000	.0971	.1961	.2955	.3952	.4951	.5952	.6955	.7961	.8971	1.0000	.7845	.78421
2,500	-6	0.0000	0.0969	0.1961	0.2957	0.3957	0.4960	0.5964	0.6970	0.7978	0.8988	1.0000	0.7862	
2,500	-5	.0000	.0942	.1924	.2914	.3911	.4913	.5919	.6930	.7946	.8968	1.0000	.7829	
2,500	-4	.0000	.0925	.1900	.2886	.3879	.4879	.5883	.6894	.7912	.8941	1.0000	.7794	
2,500	-3	.0000	.0919	.1891	.2875	.3866	.4864	.5868	.6878	.7895	.8925	1.0000	.7778	
2,500	-2	.0000	.0917	.1888	.2871	.3862	.4859	.5862	.6872	.7889	.8919	1.0000	.7772	
2,500	-1	.0000	.0916	.1887	.2870	.3861	.4858	.5861	.6870	.7887	.8917	1.0000	.7770	
2,500	0	.0000	.0916	.1887	.2869	.3860	.4857	.5860	.6869	.7887	.8916	1.0000	.7769	
2,500	1	.0000	.0916	.1886	.2869	.3860	.4857	.5860	.6869	.7886	.8916	1.0000	.7769	
3,000	-6	0.0000	0.0984	0.1978	0.2975	0.3974	0.4973	0.5973	0.6974	0.7975	0.8977	0.9980	0.7860	0.78592
3,000	-5	.0000	.0967	.1958	.2955	.3954	.4957	.5961	.6967	.7974	.8983	.9994	.7858	.78574
3,000	-4	.0000	.0922	.1898	.2888	.3887	.4892	.5903	.6919	.7940	.8966	.9998	.7822	.78201
3,000	-3	.0000	.0872	.1829	.2806	.3797	.4799	.5811	.6834	.7870	.8921	.9999	.7749	.77457
3,000	-2	.0000	.0847	.1793	.2762	.3746	.4744	.5753	.6774	.7811	.8872	1.0000	.7691	.76858
3,000	-1	.0000	.0838	.1779	.2745	.3727	.4722	.5730	.6750	.7786	.8847	1.0000	.7666	.76599
3,000	0	.0000	.0835	.1775	.2740	.3721	.4715	.5722	.6741	.7777	.8838	1.0000	.7657	.76507
3,000	1	.0000	.0834	.1774	.2738	.3719	.4713	.5719	.6739	.7774	.8835	1.0000	.7654	.76468
3,500	-6	0.0000	0.0905	0.1864	0.2834	0.3808	0.4786	0.5766	0.6748	0.7731	0.8716	0.9702	0.7618	
3,500	-5	.0000	.0957	.1942	.2931	.3923	.4917	.5912	.6909	.7907	.8905	.9905	.7792	
3,500	-4	.0000	.0951	.1936	.2929	.3927	.4928	.5932	.6939	.7947	.8958	.9970	.7831	
3,500	-3	.0000	.0890	.1858	.2844	.3842	.4849	.5864	.6886	.7915	.8950	.9990	.7796	
3,500	-2	.0000	.0808	.1742	.2708	.3696	.4701	.5722	.6759	.7814	.8890	.9997	.7691	
3,500	-1	.0000	.0763	.1674	.2624	.3600	.4597	.5613	.6650	.7712	.8811	.9999	.7588	
3,500	0	.0000	.0746	.1649	.2592	.3562	.4554	.5567	.6601	.7662	.8765	1.0000	.7538	
3,500	1	.0000	.0741	.1640	.2581	.3550	.4540	.5551	.6584	.7645	.8747	1.0000	.7521	
4,000	-6	0.0000	0.0493	0.1206	0.1983	0.2793	0.3625	0.4473	0.5333	0.6203	0.7081	0.7965	0.6103	0.60819
4,000	-5	.0000	.0791	.1695	.2622	.3561	.4508	.5460	.6417	.7377	.8339	.9305	.7266	.72579
4,000	-4	.0000	.0911	.1875	.2850	.3831	.4816	.5803	.6793	.7786	.8779	.9775	.7671	.76679
4,000	-3	.0000	.0915	.1887	.2874	.3868	.4868	.5873	.6882	.7894	.8910	.9928	.7777	.77750
4,000	-2	.0000	.0830	.1776	.2753	.3748	.4758	.5781	.6814	.7858	.8913	.9977	.7738	.77333
4,000	-1	.0000	.0724	.1622	.2569	.3548	.4554	.5584	.6638	.7718	.8832	.9993	.7592	.75866
4,000	0	.0000	.0670	.1537	.2462	.3425	.4419	.5442	.6495	.7586	.8730	.9998	.7458	.74535
4,000	1	.0000	.0651	.1506	.2422	.3378	.4366	.5384	.6434	.7524	.8673	.9999	.7396	.73918
4,500	-6	0.0000	0.0072	0.0255	0.0516	0.0837	0.1205	0.1612	0.2050	0.2517	0.3007	0.3518	0.2462	
4,500	-5	.0000	.0350	.0938	.1609	.2328	.3078	.3851	.4642	.5447	.6264	.7090	.5354	
4,500	-4	.0000	.0700	.1555	.2444	.3351	.4271	.5199	.6133	.7073	.8017	.8965	.6965	
4,500	-3	.0000	.0861	.1805	.2766	.3736	.4714	.5696	.6682	.7672	.8665	.9660	.7558	
4,500	-2	.0000	.0854	.1806	.2783	.3773	.4775	.5785	.6802	.7826	.8856	.9891	.7708	
4,500	-1	.0000	.0732	.1639	.2595	.3583	.4596	.5631	.6685	.7759	.8852	.9965	.7634	
4,500	0	.0000	.0622	.1468	.2385	.3349	.4350	.5387	.6460	.7574	.8740	.9989	.7443	
4,500	1	.0000	.0575	.1390	.2284	.3229	.4217	.5246	.6316	.7437	.8631	.9997	.7304	

TABLE III.- CONCENTRATION ν_3 OF DIATOMIC NITROGEN (N_2) - Concluded

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	α												
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From unpublished tables)
5,000	-6	0.0000	0.0007	0.0027	0.0059	0.0104	0.0161	0.0228	0.0307	0.0396	0.0496	0.0605	0.0386	0.03778
5,000	-5	.0000	.0060	.0218	.0446	.0732	.1062	.1431	.1831	.2259	.2711	.3184	.2208	.21816
5,000	-4	.0000	.0316	.0868	.1508	.2200	.2926	.3677	.4447	.5233	.6031	.6841	.5141	.51183
5,000	-3	.0000	.0666	.1502	.2378	.3276	.4187	.5109	.6039	.6975	.7917	.8863	.6867	.68561
5,000	-2	.0000	.0814	.1741	.2694	.3661	.4639	.5625	.6617	.7615	.8618	.9625	.7500	.74941
5,000	-1	.0000	.0756	.1672	.2632	.3619	.4626	.5650	.6689	.7741	.8805	.9880	.7619	.76126
5,000	0	.0000	.0607	.1450	.2370	.3341	.4352	.5400	.6482	.7600	.8758	.9962	.7469	.74625
5,000	1	.0000	.0519	.1303	.2181	.3122	.4114	.5155	.6246	.7395	.8622	.9988	.7259	.72589
5,500	-6	0.0000	0.0001	0.0004	0.0008	0.0014	0.0022	0.0032	0.0043	0.0056	0.0071	0.0087	0.0054	
5,500	-5	.0000	.0009	.0034	.0076	.0133	.0204	.0290	.0388	.0500	.0624	.0759	.0486	
5,500	-4	.0000	.0076	.0266	.0537	.0869	.1248	.1666	.2117	.2595	.3097	.3619	.2538	
5,500	-3	.0000	.0356	.0949	.1627	.2353	.3110	.3891	.4689	.5502	.6327	.7162	.5407	
5,500	-2	.0000	.0674	.1519	.2405	.3315	.4239	.5175	.6120	.7072	.8030	.8994	.6962	
5,500	-1	.0000	.0747	.1651	.2597	.3567	.4554	.5556	.6570	.7595	.8628	.9670	.7476	
5,500	0	.0000	.0614	.1465	.2391	.3367	.4380	.5426	.6502	.7605	.8736	.9894	.7476	
5,500	1	.0000	.0484	.1248	.2119	.3061	.4061	.5115	.6223	.7389	.8628	.9967	.7252	
6,000	-6	0.0000	0.0000	0.0001	0.0001	0.0003	0.0004	0.0006	0.0008	0.0010	0.0013	0.0016	0.0010	0.00097
6,000	-5	.0000	.0002	.0006	.0014	.0026	.0040	.0057	.0078	.0101	.0128	.0158	.0099	.00952
6,000	-4	.0000	.0016	.0061	.0133	.0231	.0351	.0493	.0655	.0835	.1032	.1246	.0813	.07911
6,000	-3	.0000	.0123	.0408	.0788	.1234	.1729	.2261	.2824	.3413	.4023	.4652	.3344	.32992
6,000	-2	.0000	.0445	.1124	.1876	.2668	.3487	.4326	.5180	.6046	.6923	.7809	.5946	.59172
6,000	-1	.0000	.0676	.1533	.2437	.3368	.4318	.5283	.6260	.7247	.8242	.9246	.7132	.71186
6,000	0	.0000	.0622	.1475	.2399	.3369	.4372	.5404	.6460	.7538	.8637	.9755	.7413	.74008
6,000	1	.0000	.0467	.1223	.2092	.3038	.4046	.5108	.6223	.7393	.8623	.9922	.7255	.72472
6,500	-5	0.0000	0.0000	0.0002	0.0003	0.0006	0.0010	0.0014	0.0019	0.0025	0.0031	0.0038	0.0024	
6,500	-4	.0000	.0004	.0015	.0034	.0060	.0093	.0133	.0180	.0234	.0294	.0360	.0227	
6,500	-3	.0000	.0036	.0134	.0285	.0479	.0711	.0976	.1270	.1591	.1934	.2299	.1552	
6,500	-2	.0000	.0223	.0664	.1205	.1807	.2452	.3129	.3831	.4554	.5294	.6049	.4470	
6,500	-1	.0000	.0540	.1302	.2127	.2988	.3873	.4777	.5696	.6626	.7567	.8518	.6519	
6,500	0	.0000	.0608	.1445	.2351	.3301	.4282	.5288	.6316	.7362	.8426	.9505	.7241	
6,500	1	.0000	.0461	.1215	.2086	.3034	.4043	.5105	.6217	.7376	.8583	.9841	.7240	
7,000	-4	0.0000	0.0001	0.0005	0.0010	0.0018	0.0028	0.0040	0.0055	0.0071	0.0090	0.0111	0.0069	0.00644
7,000	-3	.0000	.0011	.0043	.0096	.0167	.0256	.0361	.0483	.0619	.0770	.0934	.0603	.05687
7,000	-2	.0000	.0092	.0316	.0629	.1005	.1431	.1897	.2395	.2920	.3469	.4039	.2858	.27713
7,000	-1	.0000	.0370	.0984	.1685	.2436	.3221	.4031	.4862	.5708	.6569	.7442	.5610	.55468
7,000	0	.0000	.0560	.1355	.2224	.3137	.4081	.5050	.6039	.7046	.8068	.9105	.6929	.68968
7,000	1	.0000	.0458	.1210	.2078	.3022	.4026	.5078	.6175	.7314	.8491	.9708	.7180	.71596
8,000	-3	0.0000	0.0002	0.0006	0.0014	0.0025	0.0038	0.0055	0.0075	0.0097	0.0123	0.0151	0.0095	0.00834
8,000	-2	.0000	.0015	.0058	.0128	.0222	.0338	.0475	.0631	.0806	.0998	.1206	.0785	.07131
8,000	-1	.0000	.0115	.0386	.0754	.1188	.1673	.2199	.2757	.3342	.3951	.4581	.3273	.31206
8,000	0	.0000	.0375	.1003	.1726	.2504	.3322	.4170	.5042	.5934	.6843	.7768	.5830	.57298
8,000	1	.0000	.0434	.1156	.1992	.2901	.3863	.4869	.5913	.6989	.8096	.9231	.6864	.68145
9,000	-2	0.0000	0.0003	0.0013	0.0030	0.0052	0.0081	0.0116	0.0157	0.0204	0.0256	0.0314	0.0198	0.01649
9,000	-1	.0000	.0031	.0117	.0249	.0423	.0632	.0873	.1142	.1437	.1755	.2094	.1402	.12350
9,000	0	.0000	.0184	.0574	.1071	.1639	.2259	.2918	.3609	.4327	.5068	.5829	.4243	.40199
9,000	1	.0000	.0362	.1003	.1760	.2590	.3473	.4399	.5360	.6352	.7372	.8415	.6237	.61154
10,000	-1	0.0000	0.0010	0.0038	0.0083	0.0145	0.0223	0.0317	0.0424	0.0546	0.0681	0.0828	0.0531	0.04220
10,000	0	.0000	.0077	.0271	.0551	.0894	.1289	.1727	.2201	.2705	.3237	.3793	.2646	.23260
10,000	1	.0000	.0261	.0774	.1407	.2119	.2888	.3702	.4553	.5435	.6345	.7280	.5332	.50811

TABLE IV.- CONCENTRATION ν_4 OF DIATOMIC OXYGEN (O_2)

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	α												
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From unpublished tables)
1,500	-6	0.9992	0.8987	0.7986	0.6986	0.5986	0.4986	0.3987	0.2988	0.1990	0.0993	0.0000	0.2105	
1,500	-5	.9997	.8993	.7991	.6991	.5990	.4990	.3991	.2991	.1993	.0994	.0000	.2108	
1,500	-4	.9999	.8994	.7993	.6992	.5992	.4991	.3992	.2992	.1993	.0995	.0000	.2108	
1,500	-3	1.0000	.8995	.7993	.6993	.5992	.4992	.3992	.2993	.1994	.0995	.0000	.2109	
1,500	-2	1.0000	.8995	.7994	.6993	.5992	.4992	.3992	.2993	.1994	.0995	.0000	.2109	
1,500	-1	1.0000	.8995	.7994	.6993	.5992	.4992	.3992	.2993	.1994	.0995	.0000	.2109	
1,500	0	1.0000	.8995	.7994	.6993	.5992	.4992	.3992	.2993	.1994	.0995	.0000	.2109	
1,500	1	1.0000	.8995	.7994	.6993	.5992	.4992	.3992	.2993	.1994	.0995	.0000	.2109	
2,000	-6	0.8867	0.7903	0.6960	0.6024	0.5097	0.4177	0.3269	0.2374	0.1500	0.0665	0.0000	0.1599	0.15877
2,000	-5	.9627	.8618	.7629	.6646	.5667	.4692	.3721	.2757	.1801	.0861	.0000	.1911	.19050
2,000	-4	.9880	.8858	.7855	.6856	.5860	.4868	.3878	.2891	.1909	.0935	.0000	.2022	.20185
2,000	-3	.9962	.8935	.7927	.6924	.5923	.4925	.3928	.2935	.1944	.0959	.0000	.2058	.20558
2,000	-2	.9988	.8960	.7950	.6945	.5943	.4943	.3945	.2949	.1956	.0967	.0000	.2070	.20678
2,000	-1	.9996	.8967	.7958	.6952	.5949	.4949	.3950	.2953	.1959	.0970	.0000	.2074	.20715
2,000	0	.9999	.8970	.7960	.6954	.5951	.4950	.3951	.2955	.1961	.0971	.0000	.2075	.20724
2,000	1	1.0000	.8971	.7961	.6955	.5952	.4951	.3952	.2955	.1961	.0971	.0000	.2075	.20718
2,500	-6	0.1337	0.1103	0.0891	0.0698	0.0526	0.0375	0.0246	0.0143	0.0065	0.0017	0.0000	0.0073	
2,500	-5	.4806	.4128	.3495	.2888	.2311	.1766	.1260	.0805	.0417	.0126	.0000	.0457	
2,500	-4	.7835	.6950	.6056	.5181	.4322	.3481	.2661	.1870	.1120	.0443	.0000	.1203	
2,500	-3	.9278	.8239	.7253	.6281	.5320	.4369	.3429	.2503	.1596	.0724	.0000	.1699	
2,500	-2	.9766	.8696	.7680	.6677	.5683	.4697	.3718	.2748	.1789	.0850	.0000	.1899	
2,500	-1	.9925	.8846	.7821	.6808	.5803	.4806	.3814	.2830	.1855	.0894	.0000	.1967	
2,500	0	.9976	.8894	.7866	.6850	.5842	.4841	.3845	.2857	.1876	.0909	.0000	.1989	
2,500	1	.9993	.8909	.7880	.6863	.5854	.4852	.3855	.2865	.1883	.0914	.0000	.1996	
3,000	-6	0.0034	0.0027	0.0022	0.0017	0.0012	0.0008	0.0005	0.0003	0.0001	0.0000	0.0000	0.0002	0.00015
3,000	-5	.0319	.0259	.0205	.0158	.0116	.0081	.0052	.0030	.0013	.0003	.0000	.0015	.00150
3,000	-4	.2118	.1752	.1428	.1131	.0861	.0622	.0415	.0244	.0114	.0030	.0000	.0127	.01280
3,000	-3	.5856	.5031	.4284	.3570	.2887	.2238	.1627	.1066	.0573	.0185	.0000	.0626	.06284
3,000	-2	.8428	.7376	.6420	.5493	.4587	.3702	.2840	.2007	.1215	.0492	.0000	.1303	.13027
3,000	-1	.9473	.8344	.7316	.6315	.5332	.4365	.3413	.2480	.1571	.0704	.0000	.1675	.16706
3,000	0	.9830	.8676	.7625	.6601	.5593	.4599	.3619	.2653	.1707	.0790	.0000	.1814	.18079
3,000	1	.9946	.8784	.7726	.6694	.5678	.4676	.3686	.2711	.1752	.0820	.0000	.1861	.18529
3,500	-6	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
3,500	-5	.0020	.0016	.0013	.0010	.0007	.0005	.0003	.0002	.0001	.0000	.0000	.0001	
3,500	-4	.0196	.0158	.0125	.0096	.0071	.0049	.0031	.0018	.0008	.0002	.0000	.0009	
3,500	-3	.1483	.1207	.0971	.0758	.0569	.0405	.0266	.0154	.0070	.0018	.0000	.0078	
3,500	-2	.5036	.4250	.3566	.2926	.2325	.1765	.1251	.0793	.0406	.0122	.0000	.0446	
3,500	-1	.8019	.6923	.5966	.5053	.4172	.3323	.2506	.1731	.1010	.0380	.0000	.1089	
3,500	0	.9325	.8116	.7061	.6048	.5065	.4106	.3173	.2268	.1401	.0594	.0000	.1498	
3,500	1	.9781	.8537	.7449	.6404	.5387	.4393	.3422	.2474	.1557	.0689	.0000	.1661	
4,000	-6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
4,000	-5	.0002	.0002	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.00001
4,000	-4	.0025	.0020	.0016	.0012	.0009	.0006	.0004	.0002	.0001	.0000	.0000	.0001	.00012
4,000	-3	.0238	.0191	.0151	.0115	.0085	.0059	.0038	.0021	.0009	.0002	.0000	.0011	.00113
4,000	-2	.1715	.1387	.1113	.0869	.0652	.0464	.0305	.0176	.0081	.0021	.0000	.0090	.00950
4,000	-1	.5566	.4488	.3750	.3068	.2433	.1843	.1304	.0826	.0423	.0127	.0000	.0465	.04803
4,000	0	.8190	.6997	.5990	.5043	.4140	.3276	.2453	.1678	.0966	.0355	.0000	.1044	.10560
4,000	1	.9387	.8082	.6978	.5935	.4934	.3968	.3036	.2142	.1297	.0529	.0000	.1391	.13927
4,500	-6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
4,500	-5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
4,500	-4	.0005	.0004	.0003	.0002	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000	
4,500	-3	.0049	.0039	.0031	.0024	.0017	.0012	.0008	.0004	.0002	.0000	.0000	.0002	
4,500	-2	.0448	.0357	.0281	.0215	.0158	.0110	.0071	.0040	.0018	.0004	.0000	.0020	
4,500	-1	.2651	.2139	.1725	.1356	.1028	.0739	.0492	.0289	.0134	.0035	.0000	.0150	
4,500	0	.6391	.5329	.4458	.3660	.2917	.2227	.1593	.1024	.0537	.0167	.0000	.0588	
4,500	1	.8671	.7352	.6262	.5251	.4296	.3389	.2530	.1726	.0991	.0363	.0000	.1071	

TABLE IV.- CONCENTRATION ν_4 OF DIATOMIC OXYGEN (O_2) - Concluded

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	α												
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From unpublished tables)
5,000	-6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
5,000	-5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
5,000	-4	.0001	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00001
5,000	-3	.0013	.0011	.0009	.0007	.0005	.0003	.0002	.0001	.0001	.0000	.0000	.0001	.00007
5,000	-2	.0131	.0104	.0082	.0063	.0046	.0032	.0020	.0011	.0005	.0001	.0000	.0006	.00063
5,000	-1	.1070	.0847	.0668	.0513	.0379	.0265	.0171	.0097	.0044	.0011	.0000	.0049	.00539
5,000	0	.4324	.3506	.2854	.2273	.1751	.1284	.0875	.0528	.0255	.0070	.0000	.0282	.03035
5,000	1	.7618	.6347	.5317	.4380	.3511	.2703	.1957	.1279	.0689	.0225	.0000	.0752	.07783
5,500	-6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
5,500	-5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
5,500	-4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
5,500	-3	.0005	.0004	.0003	.0002	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000	
5,500	-2	.0046	.0037	.0029	.0022	.0016	.0011	.0007	.0004	.0002	.0000	.0000	.0002	
5,500	-1	.0428	.0337	.0264	.0201	.0147	.0102	.0065	.0037	.0016	.0004	.0000	.0018	
5,500	0	.2574	.2036	.1618	.1256	.0940	.0668	.0439	.0254	.0117	.0030	.0000	.0130	
5,500	1	.6320	.5165	.4245	.3425	.2682	.2008	.1404	.0878	.0444	.0130	.0000	.0488	
6,000	-6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
6,000	-5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
6,000	-4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
6,000	-3	.0002	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00001
6,000	-2	.0019	.0016	.0012	.0009	.0007	.0005	.0003	.0002	.0001	.0000	.0000	.0001	.00010
6,000	-1	.0187	.0148	.0116	.0088	.0064	.0045	.0028	.0016	.0007	.0002	.0000	.0008	.00094
6,000	0	.1428	.1114	.0872	.0666	.0490	.0342	.0220	.0125	.0056	.0014	.0000	.0063	.00727
6,000	1	.4952	.3966	.3195	.2524	.1930	.1406	.0951	.0571	.0274	.0075	.0000	.0303	.03367
6,500	-5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
6,500	-4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
6,500	-3	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
6,500	-2	.0009	.0007	.0006	.0005	.0003	.0002	.0001	.0001	.0000	.0000	.0000	.0000	
6,500	-1	.0091	.0073	.0057	.0043	.0032	.0022	.0014	.0008	.0003	.0001	.0000	.0004	
6,500	0	.0788	.0612	.0476	.0361	.0264	.0182	.0116	.0065	.0029	.0007	.0000	.0033	
6,500	1	.3693	.2904	.2297	.1780	.1333	.0949	.0625	.0364	.0168	.0044	.0000	.0187	
7,000	-4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
7,000	-3	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00000
7,000	-2	.0005	.0004	.0003	.0002	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.00003
7,000	-1	.0049	.0039	.0031	.0023	.0017	.0012	.0008	.0004	.0002	.0000	.0000	.0002	.00026
7,000	0	.0451	.0351	.0273	.0206	.0150	.0104	.0066	.0037	.0016	.0004	.0000	.0018	.00226
7,000	1	.2662	.2063	.1609	.1229	.0906	.0634	.0410	.0234	.0106	.0027	.0000	.0118	.01411
8,000	-3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
8,000	-2	.0002	.0001	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00001
8,000	-1	.0018	.0014	.0011	.0009	.0006	.0004	.0003	.0002	.0001	.0000	.0000	.0001	.00010
8,000	0	.0173	.0136	.0106	.0080	.0058	.0040	.0026	.0014	.0006	.0002	.0000	.0007	.00092
8,000	1	.1341	.1026	.0788	.0593	.0430	.0295	.0188	.0105	.0046	.0012	.0000	.0052	.00662
9,000	-2	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
9,000	-1	.0008	.0007	.0005	.0004	.0003	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.00006
9,000	0	.0080	.0064	.0050	.0038	.0028	.0019	.0012	.0007	.0003	.0001	.0000	.0003	.00046
9,000	1	.0705	.0542	.0415	.0311	.0224	.0154	.0097	.0054	.0024	.0006	.0000	.0027	.00358
10,000	-1	0.0004	0.0004	0.0003	0.0002	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.00002
10,000	0	.0043	.0035	.0027	.0021	.0015	.0011	.0007	.0004	.0002	.0000	.0000	.0002	.00026
10,000	1	.0403	.0314	.0241	.0181	.0130	.0089	.0056	.0031	.0014	.0003	.0000	.0015	.00218

L-170

TABLE V.- CONCENTRATION ν_5 OF NITRIC OXIDE (NO)

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	α												
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From unpublished tables)
1,500	-6	0.0000	0.0010	0.0013	0.0015	0.0016	0.0016	0.0016	0.0015	0.0013	0.0009	0.0000	0.0013	
1,500	-5	.0000	.0010	.0013	.0015	.0016	.0016	.0016	.0015	.0013	.0010	.0000	.0013	
1,500	-4	.0000	.0010	.0013	.0015	.0016	.0016	.0016	.0015	.0013	.0010	.0000	.0013	
1,500	-3	.0000	.0010	.0013	.0015	.0016	.0016	.0016	.0015	.0013	.0010	.0000	.0013	
1,500	-2	.0000	.0010	.0013	.0015	.0016	.0016	.0016	.0015	.0013	.0010	.0000	.0013	
1,500	-1	.0000	.0010	.0013	.0015	.0016	.0016	.0016	.0015	.0013	.0010	.0000	.0013	
1,500	0	.0000	.0010	.0013	.0015	.0016	.0016	.0016	.0015	.0013	.0010	.0000	.0013	
1,500	1	.0000	.0010	.0013	.0015	.0016	.0016	.0016	.0015	.0013	.0010	.0000	.0013	
2,000	-6	0.0000	0.0055	0.0073	0.0083	0.0089	0.0090	0.0087	0.0080	0.0068	0.0048	0.0000	0.0070	0.00734
2,000	-5	.0000	.0057	.0076	.0087	.0093	.0095	.0093	.0086	.0075	.0055	.0000	.0076	.00804
2,000	-4	.0000	.0058	.0077	.0089	.0095	.0097	.0095	.0088	.0077	.0057	.0000	.0079	.00828
2,000	-3	.0000	.0058	.0078	.0089	.0095	.0097	.0095	.0089	.0078	.0058	.0000	.0079	.00835
2,000	-2	.0000	.0058	.0078	.0089	.0096	.0098	.0096	.0089	.0078	.0058	.0000	.0079	.00838
2,000	-1	.0000	.0058	.0078	.0089	.0096	.0098	.0096	.0089	.0078	.0058	.0000	.0080	.00839
2,000	0	.0000	.0058	.0078	.0089	.0096	.0098	.0096	.0089	.0078	.0058	.0000	.0080	.00839
2,000	1	.0000	.0058	.0078	.0089	.0096	.0098	.0096	.0089	.0078	.0058	.0000	.0080	.00839
2,500	-6	0.0000	0.0061	0.0078	0.0085	0.0085	0.0080	0.0071	0.0059	0.0043	0.0023	0.0000	0.0045	
2,500	-5	.0000	.0116	.0153	.0171	.0177	.0174	.0161	.0139	.0107	.0063	.0000	.0112	
2,500	-4	.0000	.0149	.0200	.0228	.0241	.0243	.0233	.0212	.0175	.0117	.0000	.0180	
2,500	-3	.0000	.0162	.0218	.0250	.0267	.0272	.0264	.0244	.0209	.0150	.0000	.0214	
2,500	-2	.0000	.0166	.0224	.0258	.0276	.0282	.0275	.0256	.0221	.0162	.0000	.0226	
2,500	-1	.0000	.0168	.0226	.0260	.0279	.0285	.0279	.0260	.0225	.0166	.0000	.0230	
2,500	0	.0000	.0168	.0227	.0261	.0280	.0286	.0280	.0261	.0227	.0168	.0000	.0232	
2,500	1	.0000	.0168	.0227	.0261	.0280	.0286	.0280	.0261	.0227	.0168	.0000	.0232	
3,000	-6	0.0000	0.0020	0.0025	0.0027	0.0027	0.0025	0.0022	0.0018	0.0013	0.0007	0.0000	0.0013	0.00138
3,000	-5	.0000	.0061	.0077	.0083	.0083	.0078	.0068	.0055	.0040	.0021	.0000	.0042	.00430
3,000	-4	.0000	.0155	.0201	.0221	.0224	.0213	.0191	.0159	.0116	.0063	.0000	.0122	.01256
3,000	-3	.0000	.0256	.0342	.0387	.0405	.0401	.0376	.0330	.0260	.0157	.0000	.0269	.02770
3,000	-2	.0000	.0306	.0415	.0476	.0507	.0512	.0494	.0451	.0377	.0256	.0000	.0387	.03973
3,000	-1	.0000	.0323	.0441	.0509	.0545	.0555	.0541	.0500	.0428	.0305	.0000	.0438	.04489
3,000	0	.0000	.0329	.0450	.0520	.0558	.0569	.0556	.0517	.0445	.0323	.0000	.0456	.04670
3,000	1	.0000	.0331	.0453	.0524	.0562	.0574	.0561	.0523	.0451	.0329	.0000	.0462	.04726
3,500	-6	0.0000	0.0008	0.0010	0.0011	0.0011	0.0010	0.0009	0.0007	0.0005	0.0003	0.0000	0.0005	
3,500	-5	.0000	.0026	.0033	.0035	.0035	.0033	.0029	.0023	.0016	.0009	.0000	.0017	
3,500	-4	.0000	.0080	.0101	.0109	.0108	.0101	.0089	.0072	.0052	.0027	.0000	.0054	
3,500	-3	.0000	.0214	.0277	.0302	.0305	.0289	.0257	.0212	.0154	.0083	.0000	.0161	
3,500	-2	.0000	.0382	.0513	.0580	.0604	.0593	.0551	.0477	.0367	.0214	.0000	.0382	
3,500	-1	.0000	.0473	.0651	.0750	.0798	.0805	.0773	.0699	.0575	.0377	.0000	.0592	
3,500	0	.0000	.0507	.0703	.0816	.0875	.0891	.0866	.0797	.0675	.0470	.0000	.0692	
3,500	1	.0000	.0518	.0720	.0837	.0901	.0920	.0898	.0831	.0711	.0506	.0000	.0728	
4,000	-6	0.0000	0.0003	0.0004	0.0005	0.0005	0.0005	0.0004	0.0003	0.0002	0.0001	0.0000	0.0003	0.00026
4,000	-5	.0000	.0012	.0016	.0017	.0017	.0016	.0014	.0012	.0008	.0004	.0000	.0009	.00089
4,000	-4	.0000	.0041	.0052	.0057	.0056	.0052	.0046	.0037	.0027	.0014	.0000	.0028	.00290
4,000	-3	.0000	.0127	.0162	.0175	.0175	.0163	.0144	.0117	.0083	.0044	.0000	.0088	.00906
4,000	-2	.0000	.0327	.0428	.0471	.0476	.0453	.0404	.0334	.0243	.0131	.0000	.0254	.02620
4,000	-1	.0000	.0549	.0751	.0855	.0895	.0882	.0822	.0713	.0550	.0322	.0000	.0572	.05833
4,000	0	.0000	.0659	.0924	.1073	.1147	.1159	.1113	.1005	.0824	.0536	.0000	.0850	.08574
4,000	1	.0000	.0698	.0987	.1155	.1243	.1268	.1231	.1131	.0951	.0652	.0000	.0977	.09805
4,500	-6	0.0000	0.0001	0.0001	0.0001	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	
4,500	-5	.0000	.0005	.0007	.0008	.0008	.0008	.0007	.0006	.0004	.0002	.0000	.0004	
4,500	-4	.0000	.0022	.0029	.0032	.0032	.0030	.0026	.0021	.0015	.0008	.0000	.0016	
4,500	-3	.0000	.0076	.0097	.0105	.0105	.0098	.0086	.0070	.0050	.0027	.0000	.0052	
4,500	-2	.0000	.0228	.0294	.0320	.0319	.0300	.0264	.0215	.0154	.0082	.0000	.0162	
4,500	-1	.0000	.0517	.0694	.0774	.0792	.0761	.0687	.0573	.0422	.0231	.0000	.0441	
4,500	0	.0000	.0751	.1056	.1220	.1290	.1285	.1210	.1062	.0833	.0499	.0000	.0864	
4,500	1	.0000	.0849	.1218	.1430	.1538	.1561	.1504	.1363	.1120	.0731	.0000	.1155	

L-179

TABLE V.- CONCENTRATION ν_5 OF NITRIC OXIDE (NO) - Concluded

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	α												
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From unpublished tables)
5,000	-6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00002
5,000	-5	.0000	.0001	.0002	.0003	.0003	.0003	.0003	.0002	.0002	.0001	.0000	.0002	.00020
5,000	-4	.0000	.0010	.0014	.0017	.0017	.0016	.0015	.0012	.0009	.0005	.0000	.0009	.00095
5,000	-3	.0000	.0045	.0060	.0065	.0066	.0062	.0055	.0045	.0032	.0017	.0000	.0034	.00347
5,000	-2	.0000	.0154	.0199	.0216	.0216	.0202	.0178	.0145	.0103	.0055	.0000	.0109	.01123
5,000	-1	.0000	.0421	.0557	.0612	.0617	.0583	.0518	.0425	.0306	.0164	.0000	.0321	.03307
5,000	0	.0000	.0768	.1071	.1222	.1274	.1245	.1144	.0975	.0733	.0413	.0000	.0765	.07771
5,000	1	.0000	.0956	.1386	.1627	.1743	.1756	.1672	.1489	.1189	.0733	.0000	.1230	.12273
5,500	-6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
5,500	-5	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0000	.0000	.0001	
5,500	-4	.0000	.0003	.0006	.0007	.0008	.0008	.0007	.0006	.0004	.0002	.0000	.0005	
5,500	-3	.0000	.0024	.0034	.0039	.0040	.0039	.0034	.0028	.0020	.0011	.0000	.0021	
5,500	-2	.0000	.0102	.0135	.0149	.0149	.0141	.0124	.0101	.0072	.0039	.0000	.0076	
5,500	-1	.0000	.0323	.0424	.0465	.0466	.0438	.0387	.0316	.0226	.0121	.0000	.0237	
5,500	0	.0000	.0719	.0989	.1114	.1143	.1099	.0991	.0826	.0605	.0330	.0000	.0633	
5,500	1	.0000	.1016	.1479	.1731	.1841	.1835	.1722	.1502	.1163	.0682	.0000	.1209	
6,000	-6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
6,000	-5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.00002
6,000	-4	.0000	.0001	.0002	.0003	.0003	.0003	.0003	.0003	.0002	.0001	.0000	.0002	.00021
6,000	-3	.0000	.0011	.0017	.0021	.0022	.0022	.0020	.0017	.0012	.0007	.0000	.0013	.00134
6,000	-2	.0000	.0063	.0089	.0101	.0103	.0098	.0087	.0071	.0051	.0027	.0000	.0054	.00560
6,000	-1	.0000	.0240	.0320	.0352	.0353	.0333	.0294	.0240	.0172	.0091	.0000	.0180	.01874
6,000	0	.0000	.0652	.0860	.0959	.0975	.0927	.0827	.0681	.0493	.0265	.0000	.0517	.05334
6,000	1	.0000	.1032	.1499	.1743	.1837	.1809	.1672	.1430	.1079	.0609	.0000	.1125	.11364
6,500	-5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
6,500	-4	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0000	.0000	.0001	
6,500	-3	.0000	.0005	.0008	.0010	.0011	.0011	.0010	.0009	.0007	.0004	.0000	.0007	
6,500	-2	.0000	.0036	.0055	.0064	.0067	.0065	.0059	.0049	.0036	.0019	.0000	.0037	
6,500	-1	.0000	.0173	.0237	.0265	.0268	.0254	.0225	.0184	.0132	.0071	.0000	.0139	
6,500	0	.0000	.0533	.0724	.0804	.0814	.0771	.0685	.0561	.0404	.0216	.0000	.0424	
6,500	1	.0000	.1010	.1458	.1682	.1756	.1710	.1560	.1313	.0972	.0536	.0000	.1016	
7,000	-4	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.00004
7,000	-3	.0000	.0002	.0004	.0005	.0005	.0006	.0005	.0005	.0003	.0002	.0000	.0004	.00037
7,000	-2	.0000	.0019	.0031	.0038	.0041	.0041	.0038	.0032	.0024	.0013	.0000	.0025	.00255
7,000	-1	.0000	.0119	.0171	.0195	.0201	.0192	.0172	.0141	.0102	.0055	.0000	.0107	.01113
7,000	0	.0000	.0437	.0599	.0667	.0676	.0640	.0568	.0465	.0334	.0178	.0000	.0350	.03647
7,000	1	.0000	.0957	.1374	.1573	.1629	.1573	.1421	.1183	.0865	.0471	.0000	.0906	.09288
8,000	-3	0.0000	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.0001	0.00010
8,000	-2	.0000	.0006	.0010	.0013	.0014	.0015	.0014	.0012	.0009	.0005	.0000	.0009	.00095
8,000	-1	.0000	.0049	.0079	.0096	.0104	.0102	.0094	.0079	.0058	.0031	.0000	.0060	.00619
8,000	0	.0000	.0270	.0390	.0445	.0458	.0437	.0391	.0321	.0232	.0124	.0000	.0243	.02524
8,000	1	.0000	.0799	.1143	.1301	.1336	.1279	.1144	.0943	.0682	.0367	.0000	.0715	.07389
9,000	-2	0.0000	0.0002	0.0004	0.0005	0.0005	0.0006	0.0005	0.0005	0.0004	0.0002	0.0000	0.0004	0.00036
9,000	-1	.0000	.0020	.0034	.0044	.0049	.0050	.0047	.0040	.0030	.0017	.0000	.0031	.00310
9,000	0	.0000	.0151	.0236	.0281	.0297	.0289	.0262	.0218	.0159	.0086	.0000	.0166	.01708
9,000	1	.0000	.0618	.0900	.1031	.1063	.1018	.0910	.0750	.0541	.0290	.0000	.0568	.05874
10,000	-1	0.0000	0.0009	0.0016	0.0021	0.0024	0.0025	0.0023	0.0020	0.0015	0.0009	0.0000	0.0016	0.00152
10,000	0	.0000	.0081	.0136	.0169	.0184	.0183	.0169	.0143	.0105	.0058	.0000	.0110	.01097
10,000	1	.0000	.0450	.0680	.0794	.0828	.0799	.0719	.0594	.0430	.0231	.0000	.0451	.04640

L-179

TABLE VI.- COMPRESSIBILITY FACTOR Z CORRESPONDING TO TABLES I TO V

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	α												
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From reference 2)
1,500	-6	1.0008	1.0008	1.0007	1.0007	1.0006	1.0006	1.0005	1.0004	1.0004	1.0003	1.0000	1.0004	
1,500	-5	1.0003	1.0002	1.0002	1.0002	1.0002	1.0002	1.0002	1.0001	1.0001	1.0001	1.0000	1.0001	
1,500	-4	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0000	1.0000	1.0000	1.0000	1.0000	
1,500	-3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,500	-2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,500	-1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,500	0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,500	1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
2,000	-6	1.1133	1.1070	1.1004	1.0934	1.0859	1.0778	1.0688	1.0586	1.0466	1.0310	1.0000	1.0481	1.0490
2,000	-5	1.0373	1.0353	1.0332	1.0310	1.0286	1.0261	1.0232	1.0200	1.0162	1.0112	1.0000	1.0166	1.0170
2,000	-4	1.0120	1.0113	1.0107	1.0100	1.0092	1.0084	1.0075	1.0065	1.0053	1.0037	1.0000	1.0054	1.0055
2,000	-3	1.0038	1.0036	1.0034	1.0032	1.0029	1.0027	1.0024	1.0021	1.0017	1.0012	1.0000	1.0017	1.0017
2,000	-2	1.0012	1.0011	1.0011	1.0010	1.0009	1.0008	1.0008	1.0007	1.0005	1.0004	1.0000	1.0005	1.0005
2,000	-1	1.0004	1.0004	1.0003	1.0003	1.0003	1.0003	1.0002	1.0002	1.0002	1.0001	1.0000	1.0002	1.0001
2,000	0	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0000	1.0000	1.0001	1.0000
2,000	1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	.9999
2,500	-6	1.8663	1.7867	1.7071	1.6260	1.5432	1.4586	1.3718	1.2828	1.1914	1.0972	1.0000	1.2021	
2,500	-5	1.5194	1.4813	1.4429	1.4026	1.3601	1.3148	1.2659	1.2126	1.1530	1.0842	1.0000	1.1602	
2,500	-4	1.2105	1.1975	1.1844	1.1705	1.1557	1.1398	1.1222	1.1024	1.0793	1.0499	1.0000	1.0822	
2,500	-3	1.0722	1.0680	1.0638	1.0594	1.0546	1.0495	1.0439	1.0375	1.0299	1.0202	1.0000	1.0309	
2,500	-2	1.0234	1.0221	1.0208	1.0194	1.0179	1.0162	1.0144	1.0124	1.0100	1.0069	1.0000	1.0103	
2,500	-1	1.0075	1.0070	1.0066	1.0062	1.0057	1.0052	1.0046	1.0040	1.0032	1.0022	1.0000	1.0033	
2,500	0	1.0024	1.0022	1.0021	1.0020	1.0018	1.0016	1.0015	1.0013	1.0010	1.0007	1.0000	1.0011	
2,500	1	1.0007	1.0007	1.0007	1.0006	1.0006	1.0005	1.0005	1.0004	1.0003	1.0002	1.0000	1.0003	
3,000	-6	1.9966	1.8969	1.7975	1.6981	1.5987	1.4993	1.3999	1.3005	1.2010	1.1016	1.0020	1.2125	1.2125
3,000	-5	1.9681	1.8713	1.7759	1.6804	1.5846	1.4885	1.3919	1.2948	1.1973	1.0992	1.0006	1.2085	1.2084
3,000	-4	1.7882	1.7170	1.6472	1.5760	1.5028	1.4273	1.3491	1.2678	1.1830	1.0940	1.0002	1.1930	1.1926
3,000	-3	1.4144	1.3842	1.3545	1.3237	1.2911	1.2562	1.2185	1.1769	1.1297	1.0737	1.0001	1.1355	1.1349
3,000	-2	1.1572	1.1471	1.1372	1.1269	1.1160	1.1042	1.0913	1.0768	1.0597	1.0380	1.0000	1.0619	1.0614
3,000	-1	1.0527	1.0495	1.0463	1.0430	1.0396	1.0358	1.0316	1.0270	1.0215	1.0144	1.0000	1.0222	1.0220
3,000	0	1.0170	1.0160	1.0150	1.0139	1.0128	1.0116	1.0103	1.0088	1.0071	1.0048	1.0000	1.0073	1.0072
3,000	1	1.0054	1.0051	1.0048	1.0044	1.0041	1.0037	1.0033	1.0028	1.0023	1.0016	1.0000	1.0023	1.0022
3,500	-6	1.9998	1.9085	1.8124	1.7155	1.6180	1.5204	1.4225	1.3245	1.2263	1.1281	1.0298	1.2376	
3,500	-5	1.9980	1.9000	1.8013	1.7024	1.6035	1.5046	1.4056	1.3066	1.2076	1.1086	1.0095	1.2190	
3,500	-4	1.9804	1.8811	1.7837	1.6866	1.5894	1.4921	1.3947	1.2971	1.1993	1.1015	1.0030	1.2106	
3,500	-3	1.8517	1.7689	1.6895	1.6096	1.5284	1.4457	1.3613	1.2749	1.1862	1.0950	1.0010	1.1965	
3,500	-2	1.4964	1.4560	1.4178	1.3785	1.3375	1.2941	1.2476	1.1972	1.1413	1.0774	1.0003	1.1481	
3,500	-1	1.1981	1.1841	1.1709	1.1573	1.1429	1.1276	1.1108	1.0921	1.0704	1.0432	1.0001	1.0731	
3,500	0	1.0675	1.0630	1.0588	1.0544	1.0498	1.0448	1.0394	1.0333	1.0262	1.0171	1.0000	1.0271	
3,500	1	1.0219	1.0204	1.0191	1.0177	1.0162	1.0147	1.0129	1.0110	1.0087	1.0058	1.0000	1.0090	
4,000	-6	2.0000	1.9504	1.8789	1.8013	1.7202	1.6370	1.5523	1.4663	1.3794	1.2918	1.2035	1.3895	1.3915
4,000	-5	1.9997	1.9195	1.8287	1.7359	1.6421	1.5475	1.4525	1.3571	1.2615	1.1656	1.0695	1.2725	1.2733
4,000	-4	1.9975	1.9028	1.8057	1.7081	1.6104	1.5126	1.4147	1.3167	1.2187	1.1206	1.0225	1.2300	1.2302
4,000	-3	1.9762	1.8767	1.7799	1.6835	1.5873	1.4910	1.3946	1.2980	1.2013	1.1044	1.0072	1.2125	1.2123
4,000	-2	1.8285	1.7456	1.6683	1.5908	1.5123	1.4325	1.3510	1.2675	1.1818	1.0935	1.0023	1.1918	1.1909
4,000	-1	1.4634	1.4240	1.3877	1.3508	1.3124	1.2721	1.2290	1.1824	1.1308	1.0719	1.0007	1.1370	1.1349
4,000	0	1.1810	1.1674	1.1549	1.1422	1.1288	1.1146	1.0992	1.0821	1.0624	1.0379	1.0002	1.0648	1.0631
4,000	1	1.0613	1.0569	1.0529	1.0488	1.0445	1.0399	1.0349	1.0293	1.0228	1.0146	1.0001	1.0237	1.0227
4,500	-6	2.0000	1.9927	1.9744	1.9482	1.9161	1.8793	1.8387	1.7948	1.7482	1.6993	1.6482	1.7537	
4,500	-5	2.0000	1.9644	1.9055	1.8382	1.7663	1.6913	1.6141	1.5352	1.4549	1.3734	1.2910	1.4642	
4,500	-4	1.9995	1.9274	1.8413	1.7522	1.6615	1.5698	1.4774	1.3845	1.2911	1.1974	1.1035	1.3019	
4,500	-3	1.9951	1.9024	1.8067	1.7106	1.6142	1.5176	1.4210	1.3243	1.2276	1.1308	1.0340	1.2387	
4,500	-2	1.9552	1.8561	1.7618	1.6682	1.5749	1.4815	1.3880	1.2943	1.2002	1.1057	1.0109	1.2110	
4,500	-1	1.7349	1.6612	1.5942	1.5274	1.4597	1.3904	1.3191	1.2453	1.1685	1.0882	1.0035	1.1775	
4,500	0	1.3609	1.3298	1.3018	1.2736	1.2444	1.2137	1.1810	1.1453	1.1056	1.0594	1.0011	1.1104	
4,500	1	1.1329	1.1225	1.1131	1.1036	1.0937	1.0833	1.0720	1.0596	1.0452	1.0275	1.0003	1.0470	

TABLE VI.- COMPRESSIBILITY FACTOR Z CORRESPONDING TO TABLES I TO V - Concluded

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	α												
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From reference 2)
5,000	-6	2.0000	1.9993	1.9973	1.9940	1.9896	1.9839	1.9771	1.9693	1.9603	1.9504	1.9395	1.9614	1.9628
5,000	-5	2.0000	1.9938	1.9780	1.9551	1.9265	1.8935	1.8567	1.8167	1.7739	1.7288	1.6816	1.7790	1.7817
5,000	-4	1.9999	1.9673	1.9117	1.8474	1.7782	1.7057	1.6308	1.5541	1.4758	1.3964	1.3159	1.4849	1.4872
5,000	-3	1.9987	1.9279	1.8430	1.7550	1.6654	1.5747	1.4834	1.3915	1.2992	1.2066	1.1137	1.3099	1.3108
5,000	-2	1.9869	1.8928	1.7978	1.7027	1.6077	1.5127	1.4177	1.3227	1.2276	1.1326	1.0375	1.2386	1.2387
5,000	-1	1.8930	1.7976	1.7103	1.6243	1.5385	1.4526	1.3661	1.2789	1.1910	1.1020	1.0120	1.2011	1.2002
5,000	0	1.5676	1.5120	1.4625	1.4134	1.3634	1.3118	1.2581	1.2015	1.1412	1.0759	1.0038	1.1484	1.1456
5,000	1	1.2382	1.2177	1.1995	1.1812	1.1624	1.1427	1.1216	1.0986	1.0727	1.0420	1.0012	1.0759	1.0729
5,500	-6	2.0000	1.9999	1.9996	1.9992	1.9986	1.9978	1.9968	1.9957	1.9944	1.9929	1.9913	1.9945	
5,500	-5	2.0000	1.9991	1.9965	1.9923	1.9866	1.9795	1.9709	1.9611	1.9499	1.9376	1.9241	1.9513	
5,500	-4	2.0000	1.9921	1.9728	1.9455	1.9123	1.8744	1.8326	1.7877	1.7401	1.6901	1.6381	1.7457	
5,500	-3	1.9995	1.9617	1.9013	1.8331	1.7605	1.6850	1.6074	1.5282	1.4477	1.3662	1.2838	1.4571	
5,500	-2	1.9954	1.9187	1.8317	1.7424	1.6520	1.5609	1.4694	1.3775	1.2854	1.1931	1.1006	1.2960	
5,500	-1	1.9572	1.8593	1.7660	1.6737	1.5820	1.4905	1.3991	1.3077	1.2163	1.1247	1.0330	1.2268	
5,500	0	1.7426	1.6631	1.5928	1.5239	1.4550	1.3853	1.3144	1.2419	1.1673	1.0904	1.0106	1.1760	
5,500	1	1.3680	1.3334	1.3027	1.2724	1.2416	1.2096	1.1759	1.1398	1.1004	1.0560	1.0033	1.1051	
6,000	-6	2.0000	2.0000	1.9999	1.9999	1.9997	1.9996	1.9994	1.9992	1.9990	1.9987	1.9984	1.9990	2.0140
6,000	-5	2.0000	1.9998	1.9993	1.9985	1.9974	1.9960	1.9942	1.9922	1.9898	1.9872	1.9842	1.9901	1.9950
6,000	-4	2.0000	1.9983	1.9937	1.9864	1.9766	1.9646	1.9504	1.9343	1.9163	1.8967	1.8754	1.9185	1.9219
6,000	-3	1.9998	1.9864	1.9574	1.9190	1.8743	1.8249	1.7719	1.7159	1.6575	1.5970	1.5348	1.6643	1.6689
6,000	-2	1.9981	1.9476	1.8775	1.8014	1.7223	1.6411	1.5584	1.4747	1.3902	1.3049	1.2191	1.4000	1.4025
6,000	-1	1.9813	1.8936	1.8031	1.7123	1.6214	1.5304	1.4395	1.3485	1.2575	1.1664	1.0754	1.2680	1.2685
6,000	0	1.8572	1.7632	1.6793	1.5976	1.5166	1.4358	1.3548	1.2734	1.1913	1.1084	1.0245	1.2008	1.1992
6,000	1	1.5048	1.4555	1.4082	1.3640	1.3195	1.2740	1.2269	1.1776	1.1254	1.0693	1.0078	1.1316	1.1275
6,500	-5	2.0000	2.0000	1.9998	1.9996	1.9994	1.9990	1.9986	1.9981	1.9975	1.9969	1.9962	1.9976	2.0124
6,500	-4	2.0000	1.9996	1.9984	1.9965	1.9939	1.9905	1.9865	1.9819	1.9765	1.9706	1.9640	1.9772	1.9827
6,500	-3	1.9999	1.9959	1.9857	1.9705	1.9510	1.9277	1.9013	1.8721	1.8403	1.8062	1.7701	1.8441	1.8499
6,500	-2	1.9991	1.9734	1.9276	1.8726	1.8122	1.7480	1.6810	1.6119	1.5410	1.4686	1.3951	1.5492	1.5550
6,500	-1	1.9909	1.9214	1.8404	1.7565	1.6712	1.5851	1.4984	1.4112	1.3238	1.2361	1.1482	1.3339	1.3363
6,500	0	1.9212	1.8246	1.7355	1.6483	1.5621	1.4764	1.3910	1.3058	1.2205	1.1351	1.0495	1.2303	1.2298
6,500	1	1.6307	1.5626	1.5030	1.4452	1.3878	1.3299	1.2710	1.2106	1.1484	1.0837	1.0159	1.1557	1.1520
7,000	-4	2.0000	1.9999	1.9995	1.9989	1.9981	1.9971	1.9959	1.9945	1.9928	1.9910	1.9889	1.9930	2.0056
7,000	-3	2.0000	1.9986	1.9953	1.9899	1.9828	1.9739	1.9633	1.9513	1.9377	1.9228	1.9066	1.9394	1.9462
7,000	-2	1.9995	1.9885	1.9649	1.9330	1.8951	1.8526	1.8065	1.7573	1.7056	1.6518	1.5961	1.7117	1.7209
7,000	-1	1.9951	1.9472	1.8814	1.8096	1.7346	1.6575	1.5790	1.4993	1.4188	1.3376	1.2558	1.4281	1.4339
7,000	0	1.9549	1.8652	1.7773	1.6902	1.6037	1.5176	1.4317	1.3460	1.2604	1.1749	1.0895	1.2703	1.2715
7,000	1	1.7338	1.6522	1.5807	1.5120	1.4443	1.3768	1.3091	1.2408	1.1715	1.1011	1.0292	1.1796	1.1768
8,000	-3	2.0000	1.9998	1.9993	1.9985	1.9974	1.9960	1.9943	1.9924	1.9902	1.9877	1.9849	1.9904	2.0100
8,000	-2	1.9998	1.9978	1.9931	1.9858	1.9763	1.9647	1.9511	1.9356	1.9185	1.8997	1.8794	1.9205	1.9330
8,000	-1	1.9982	1.9821	1.9523	1.9141	1.8702	1.8220	1.7705	1.7163	1.6599	1.6017	1.5419	1.6665	1.6827
8,000	0	1.9827	1.9219	1.8501	1.7749	1.6980	1.6200	1.5414	1.4623	1.3828	1.3031	1.2232	1.3920	1.4009
8,000	1	1.8659	1.7742	1.6913	1.6114	1.5333	1.4563	1.3799	1.3039	1.2282	1.1526	1.0769	1.2369	1.2378
9,000	-2	1.9999	1.9994	1.9983	1.9965	1.9942	1.9913	1.9879	1.9838	1.9793	1.9742	1.9686	1.9798	2.0032
9,000	-1	1.9992	1.9943	1.9844	1.9703	1.9525	1.9316	1.9079	1.8817	1.8533	1.8229	1.7906	1.8567	1.8788
9,000	0	1.9920	1.9601	1.9140	1.8610	1.8036	1.7433	1.6808	1.6166	1.5511	1.4846	1.4171	1.5587	1.5814
9,000	1	1.9295	1.8478	1.7682	1.6898	1.6123	1.5356	1.4594	1.3836	1.3083	1.2332	1.1585	1.3169	1.3260
10,000	-1	1.9996	1.9978	1.9943	1.9894	1.9829	1.9751	1.9659	1.9555	1.9439	1.9311	1.9172	1.9453	1.9729
10,000	0	1.9957	1.9807	1.9565	1.9260	1.8907	1.8517	1.8097	1.7653	1.7188	1.6705	1.6207	1.7242	1.7601
10,000	1	1.9597	1.8976	1.8305	1.7618	1.6923	1.6224	1.5524	1.4822	1.4121	1.3420	1.2720	1.4202	1.4436

TABLE VII.- COMPRESSIBILITY FACTOR Z ACCORDING TO EQUATION (20)

T, °K	$\log_{10} \frac{p}{p_0}$	Values of Z for -												
		α												
		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From reference 2)
		p_0												
		1.4284×10^{-3}	1.4106×10^{-3}	1.3928×10^{-3}	1.3750×10^{-3}	1.3573×10^{-3}	1.3395×10^{-3}	1.3217×10^{-3}	1.3039×10^{-3}	1.2861×10^{-3}	1.2683×10^{-3}	1.2505×10^{-3}	1.2882×10^{-3}	
1,000	-6	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,000	-5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,000	-4	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,000	-3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,000	-2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,000	-1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,000	0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,500	-6	1.0008	1.0007	1.0007	1.0007	1.0006	1.0006	1.0005	1.0004	1.0004	1.0003	1.0000	1.0004	
1,500	-5	1.0003	1.0002	1.0002	1.0002	1.0002	1.0002	1.0002	1.0001	1.0001	1.0001	1.0000	1.0001	
1,500	-4	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0000	1.0000	1.0000	1.0000	1.0000	
1,500	-3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,500	-2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,500	-1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
1,500	0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
2,000	-6	1.1132	1.1070	1.1005	1.0936	1.0861	1.0781	1.0691	1.0590	1.0470	1.0315	1.0000	1.0485	1.0490
2,000	-5	1.0373	1.0353	1.0333	1.0311	1.0287	1.0262	1.0233	1.0201	1.0163	1.0113	1.0000	1.0168	1.0170
2,000	-4	1.0119	1.0113	1.0107	1.0100	1.0092	1.0084	1.0075	1.0065	1.0053	1.0037	1.0000	1.0055	1.0055
2,000	-3	1.0038	1.0036	1.0034	1.0032	1.0029	1.0027	1.0024	1.0021	1.0017	1.0012	1.0000	1.0017	1.0017
2,000	-2	1.0012	1.0011	1.0011	1.0010	1.0009	1.0008	1.0008	1.0007	1.0005	1.0004	1.0000	1.0005	1.0005
2,000	-1	1.0004	1.0004	1.0003	1.0003	1.0003	1.0003	1.0002	1.0002	1.0002	1.0001	1.0000	1.0002	1.0001
2,000	0	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	1.0000	1.0000	1.0000	1.0000	1.0000
2,500	-6	1.8660	1.7889	1.7100	1.6293	1.5467	1.4619	1.3749	1.2855	1.1933	1.0984	1.0000	1.2040	
2,500	-5	1.5190	1.4831	1.4455	1.4058	1.3637	1.3186	1.2699	1.2164	1.1563	1.0866	1.0000	1.1637	
2,500	-4	1.2103	1.1982	1.1855	1.1719	1.1574	1.1416	1.1243	1.1046	1.0815	1.0519	1.0000	1.0844	
2,500	-3	1.0721	1.0682	1.0642	1.0599	1.0552	1.0502	1.0446	1.0384	1.0308	1.0210	1.0000	1.0317	
2,500	-2	1.0234	1.0222	1.0209	1.0195	1.0181	1.0165	1.0147	1.0127	1.0103	1.0072	1.0000	1.0106	
2,500	-1	1.0075	1.0071	1.0067	1.0062	1.0058	1.0053	1.0047	1.0041	1.0033	1.0023	1.0000	1.0034	
2,500	0	1.0024	1.0022	1.0021	1.0020	1.0018	1.0017	1.0015	1.0013	1.0011	1.0007	1.0000	1.0011	
3,000	-6	1.9967	1.8976	1.7984	1.6994	1.6001	1.5006	1.4010	1.3013	1.2017	1.1019	1.0020	1.2132	1.2125
3,000	-5	1.9680	1.8741	1.7795	1.6847	1.5894	1.4924	1.3952	1.2976	1.1992	1.1003	1.0006	1.2106	1.2084
3,000	-4	1.7879	1.7220	1.6540	1.5837	1.5110	1.4354	1.3567	1.2745	1.1882	1.0970	1.0002	1.1983	1.1926
3,000	-3	1.4141	1.3874	1.3592	1.3294	1.2976	1.2633	1.2259	1.1842	1.1365	1.0789	1.0000	1.1424	1.1349
3,000	-2	1.1571	1.1483	1.1391	1.1293	1.1187	1.1072	1.0946	1.0802	1.0633	1.0414	1.0000	1.0654	1.0614
3,000	-1	1.0527	1.0499	1.0470	1.0438	1.0405	1.0368	1.0328	1.0282	1.0228	1.0157	1.0000	1.0235	1.0220
3,000	0	1.0170	1.0161	1.0152	1.0142	1.0131	1.0120	1.0107	1.0092	1.0075	1.0053	1.0000	1.0077	1.0072
3,500	-6	1.9998	1.9089	1.8129	1.7160	1.6185	1.5208	1.4229	1.3248	1.2265	1.1281	1.0297	1.2378	
3,500	-5	1.9980	1.9013	1.8029	1.7042	1.6052	1.5062	1.4070	1.3077	1.2084	1.1090	1.0095	1.2199	
3,500	-4	1.9799	1.8852	1.7890	1.6917	1.5947	1.4969	1.3990	1.3007	1.2019	1.1027	1.0030	1.2132	
3,500	-3	1.8481	1.7768	1.7001	1.6215	1.5408	1.4579	1.3725	1.2843	1.1933	1.0989	1.0010	1.2039	
3,500	-2	1.4961	1.4624	1.4270	1.3896	1.3499	1.3072	1.2610	1.2101	1.1527	1.0854	1.0003	1.1597	
3,500	-1	1.1979	1.1867	1.1748	1.1621	1.1486	1.1338	1.1175	1.0991	1.0775	1.0497	1.0001	1.0802	
3,500	0	1.0675	1.0639	1.0601	1.0560	1.0518	1.0471	1.0418	1.0359	1.0289	1.0198	1.0000	1.0298	
4,000	-6	2.0000	1.9505	1.8790	1.8013	1.7202	1.6370	1.5502	1.4661	1.3791	1.2913	1.2029	1.3892	1.3915
4,000	-5	1.9998	1.9201	1.8295	1.7367	1.6429	1.5482	1.4531	1.3576	1.2617	1.1657	1.0693	1.2728	1.2733
4,000	-4	1.9975	1.9049	1.8083	1.7110	1.6132	1.5152	1.4169	1.3185	1.2200	1.1213	1.0225	1.2303	1.2302
4,000	-3	1.9762	1.8829	1.7875	1.6919	1.5959	1.4988	1.4016	1.3037	1.2054	1.1065	1.0072	1.2167	1.2123
4,000	-2	1.8283	1.7574	1.6842	1.6089	1.5312	1.4511	1.3682	1.2822	1.1929	1.0998	1.0023	1.2034	1.1909
4,000	-1	1.4631	1.4323	1.4002	1.3659	1.3295	1.2903	1.2477	1.2005	1.1470	1.0835	1.0007	1.1536	1.1349
4,000	0	1.1809	1.1708	1.1600	1.1486	1.1362	1.1229	1.1082	1.0915	1.0718	1.0465	1.0002	1.0743	1.0631
4,500	-6	2.0000	1.9928	1.9744	1.9482	1.9160	1.8791	1.8383	1.7944	1.7476	1.6985	1.6473	1.7532	
4,500	-5	2.0000	1.9647	1.9058	1.8385	1.7665	1.6915	1.6141	1.5350	1.4546	1.3730	1.2904	1.4639	
4,500	-4	1.9995	1.9286	1.8429	1.7538	1.6631	1.5712	1.4786	1.3854	1.2917	1.1976	1.1032	1.3025	
4,500	-3	1.9954	1.9061	1.8117	1.7162	1.6196	1.5226	1.4253	1.3278	1.2300	1.1321	1.0339	1.2413	
4,500	-2	1.9552	1.8668	1.7757	1.6834	1.5901	1.4959	1.4008	1.3048	1.2078	1.1098	1.0108	1.2189	
4,500	-1	1.7347	1.6767	1.6159	1.5528	1.4868	1.4177	1.3450	1.2682	1.1865	1.0988	1.0034	1.1962	
4,500	0	1.3606	1.3384	1.3148	1.2897	1.2628	1.2338	1.2020	1.1664	1.1252	1.0745	1.0011	1.1303	

TABLE VII.- COMPRESSIBILITY FACTOR Z ACCORDING TO EQUATION (20) - Concluded

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	Values of Z for -												
		α												
		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From reference 2)
		ρ_0												
		1.4284×10^{-3}	1.4106×10^{-3}	1.3928×10^{-3}	1.3750×10^{-3}	1.3573×10^{-3}	1.3395×10^{-3}	1.3217×10^{-3}	1.3039×10^{-3}	1.2861×10^{-3}	1.2683×10^{-3}	1.2505×10^{-3}	1.2882×10^{-3}	
5,000	-6	2.0000	1.9993	1.9973	1.9941	1.9896	1.9839	1.9770	1.9692	1.9602	1.9502	1.9393	1.9613	1.9628
5,000	-5	2.0000	1.9939	1.9781	1.9552	1.9265	1.8934	1.8565	1.8164	1.7735	1.7282	1.6808	1.7786	1.7817
5,000	-4	2.0000	1.9680	1.9125	1.8483	1.7790	1.7064	1.6313	1.5544	1.4759	1.3961	1.3155	1.4850	1.4872
5,000	-3	1.9987	1.9304	1.8463	1.7585	1.6688	1.5779	1.4861	1.3937	1.3007	1.2073	1.1135	1.3114	1.3108
5,000	-2	1.9871	1.9010	1.8082	1.7137	1.6186	1.5229	1.4266	1.3300	1.2328	1.1353	1.0374	1.2442	1.2387
5,000	-1	1.8929	1.8155	1.7359	1.6508	1.5657	1.4787	1.3898	1.2988	1.2056	1.1101	1.0120	1.2165	1.2002
5,000	0	1.5674	1.5281	1.4862	1.4420	1.3951	1.3451	1.2912	1.2325	1.1673	1.0929	1.0038	1.1752	1.1456
5,500	-6	2.0000	1.9999	1.9996	1.9992	1.9984	1.9977	1.9966	1.9957	1.9943	1.9929	1.9908	1.9944	1.9986
5,500	-5	2.0000	1.9991	1.9965	1.9924	1.9866	1.9794	1.9709	1.9610	1.9498	1.9374	1.9238	1.9513	1.9534
5,500	-4	2.0000	1.9923	1.9752	1.9460	1.9127	1.8747	1.8328	1.7877	1.7399	1.6896	1.6374	1.7455	1.7490
5,500	-3	1.9995	1.9634	1.9035	1.8354	1.7628	1.6871	1.6092	1.5295	1.4485	1.3664	1.2833	1.4579	1.4594
5,500	-2	1.9959	1.9244	1.8395	1.7503	1.6601	1.5683	1.4758	1.3827	1.2890	1.1949	1.1004	1.2999	1.2968
5,500	-1	1.9571	1.8750	1.7866	1.6967	1.6047	1.5119	1.4181	1.3234	1.2279	1.1307	1.0329	1.2387	1.2264
5,500	0	1.7424	1.6857	1.6249	1.5614	1.4951	1.4257	1.3527	1.2755	1.1936	1.1057	1.0105	1.2033	1.1737
6,000	-6	2.0000	2.0000	1.9999	1.9999	1.9997	1.9996	1.9994	1.9992	1.9990	1.9987	1.9984	1.9990	2.0140
6,000	-5	2.0000	1.9998	1.9993	1.9987	1.9976	1.9961	1.9944	1.9922	1.9897	1.9871	1.9845	1.9899	1.9950
6,000	-4	2.0000	1.9984	1.9939	1.9866	1.9768	1.9647	1.9505	1.9343	1.9162	1.8964	1.8750	1.9185	1.9219
6,000	-3	1.9998	1.9873	1.9587	1.9205	1.8757	1.8262	1.7729	1.7166	1.6578	1.5969	1.5342	1.6647	1.6689
6,000	-2	1.9981	1.9518	1.8830	1.8074	1.7282	1.6466	1.5632	1.4785	1.3928	1.3061	1.2188	1.4027	1.4025
6,000	-1	1.9813	1.9070	1.8202	1.7305	1.6397	1.5476	1.4546	1.3608	1.2662	1.1711	1.0733	1.2772	1.2685
6,000	0	1.8571	1.7888	1.7145	1.6374	1.5580	1.4762	1.3918	1.3047	1.2146	1.1213	1.0244	1.2252	1.1992
6,500	-5	2.0000	2.0000	1.9998	1.9996	1.9994	1.9990	1.9986	1.9982	1.9972	1.9969	1.9963	1.9974	2.0124
6,500	-4	2.0000	1.9996	1.9984	1.9966	1.9939	1.9905	1.9865	1.9818	1.9765	1.9705	1.9638	1.9773	1.9827
6,500	-3	1.9999	1.9963	1.9864	1.9713	1.9518	1.9285	1.9020	1.8725	1.8405	1.8061	1.7696	1.8442	1.8499
6,500	-2	1.9991	1.9762	1.9315	1.8770	1.8166	1.7521	1.6846	1.6146	1.5427	1.4693	1.3945	1.5512	1.5550
6,500	-1	1.9913	1.9322	1.8540	1.7719	1.6860	1.5989	1.5105	1.4211	1.3308	1.2397	1.1480	1.3416	1.3363
6,500	0	1.9211	1.8499	1.7634	1.6861	1.6007	1.5133	1.4242	1.3332	1.2405	1.1459	1.0494	1.2513	1.2298
7,000	-4	2.0000	1.9999	1.9995	1.9990	1.9983	1.9970	1.9961	1.9945	1.9925	1.9907	1.9892	1.9931	2.0056
7,000	-3	2.0000	1.9989	1.9956	1.9904	1.9832	1.9743	1.9637	1.9516	1.9379	1.9227	1.9063	1.9395	1.9462
7,000	-2	1.9995	1.9902	1.9675	1.9361	1.8982	1.8556	1.8090	1.7593	1.7069	1.6522	1.5955	1.7130	1.7209
7,000	-1	1.9953	1.9559	1.8926	1.8218	1.7468	1.6688	1.5889	1.5073	1.4244	1.3404	1.2555	1.4340	1.4339
7,000	0	1.9549	1.8887	1.8083	1.7244	1.6382	1.5502	1.4607	1.3698	1.2775	1.1841	1.0893	1.2882	1.2715
8,000	-3	2.0000	1.9998	1.9993	1.9985	1.9975	1.9961	1.9944	1.9923	1.9900	1.9873	1.9844	1.9903	2.0100
8,000	-2	1.9998	1.9983	1.9940	1.9870	1.9776	1.9660	1.9437	1.9365	1.9191	1.9000	1.8791	1.9211	1.9330
8,000	-1	1.9982	1.9865	1.9588	1.9217	1.8780	1.8294	1.7770	1.7216	1.6637	1.6035	1.5414	1.6704	1.6827
8,000	0	1.9828	1.9404	1.8743	1.8015	1.7247	1.6453	1.5636	1.4804	1.3957	1.3099	1.2229	1.4055	1.4009
9,000	-2	1.9999	1.9996	1.9987	1.9972	1.9948	1.9919	1.9884	1.9843	1.9798	1.9743	1.9685	1.9802	2.0032
9,000	-1	1.9992	1.9962	1.9868	1.9743	1.9569	1.9360	1.9118	1.8850	1.8556	1.8240	1.7902	1.8591	1.8788
9,000	0	1.9919	1.9725	1.9321	1.8811	1.8244	1.7626	1.6979	1.6306	1.5610	1.4897	1.4167	1.5691	1.5814
10,000	-1	1.9995	1.9987	1.9959	1.9914	1.9852	1.9774	1.9681	1.9585	1.9451	1.9318	1.9170	1.9467	1.9729
10,000	0	1.9956	1.9881	1.9683	1.9400	1.9054	1.8660	1.8225	1.7758	1.7263	1.6744	1.6203	1.7321	1.7601

TABLE VIII.- DIMENSIONLESS RATIO $\frac{H}{RT}$ OF ENTHALPY TO TEMPERATURE, ACCORDING TO EQUATION (66)

T, °K	$\log_{10}\frac{\rho}{\rho_0}$	Values of $\frac{H}{RT}$ for -												
		α												
		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From reference 2)
		ρ_0												
		1.4284×10^{-3}	1.4106×10^{-3}	1.3928×10^{-3}	1.3750×10^{-3}	1.3573×10^{-3}	1.3395×10^{-3}	1.3217×10^{-3}	1.3039×10^{-3}	1.2861×10^{-3}	1.2683×10^{-3}	1.2505×10^{-3}	1.2882×10^{-3}	
1,000	-6	3.77	3.75	3.74	3.72	3.71	3.69	3.68	3.67	3.65	3.64	3.62	3.65	
1,000	-5	3.77	3.75	3.74	3.72	3.71	3.69	3.68	3.67	3.65	3.64	3.62	3.65	
1,000	-4	3.77	3.75	3.74	3.72	3.71	3.69	3.68	3.67	3.65	3.64	3.62	3.65	
1,000	-3	3.77	3.75	3.74	3.72	3.71	3.69	3.68	3.67	3.65	3.64	3.62	3.65	
1,000	-2	3.77	3.75	3.74	3.72	3.71	3.69	3.68	3.67	3.65	3.64	3.62	3.65	
1,000	-1	3.77	3.75	3.74	3.72	3.71	3.69	3.68	3.67	3.65	3.64	3.62	3.65	
1,000	0	3.77	3.75	3.74	3.72	3.71	3.69	3.68	3.67	3.65	3.64	3.62	3.65	
1,500	-6	3.97	3.95	3.93	3.91	3.89	3.87	3.85	3.84	3.82	3.80	3.77	3.82	
1,500	-5	3.94	3.93	3.91	3.89	3.88	3.86	3.84	3.82	3.81	3.79	3.77	3.81	
1,500	-4	3.94	3.92	3.90	3.89	3.87	3.85	3.84	3.82	3.80	3.79	3.77	3.80	
1,500	-3	3.93	3.92	3.90	3.88	3.87	3.85	3.84	3.82	3.80	3.78	3.77	3.80	
1,500	-2	3.93	3.92	3.90	3.88	3.87	3.85	3.84	3.82	3.80	3.78	3.77	3.80	
1,500	-1	3.93	3.92	3.90	3.88	3.87	3.85	3.83	3.82	3.80	3.78	3.77	3.80	
1,500	0	3.93	3.92	3.90	3.88	3.87	3.85	3.83	3.82	3.80	3.78	3.77	3.80	
2,000	-6	7.53	7.33	7.11	6.88	6.64	6.37	6.08	5.67	5.37	4.87	3.89	5.42	5.481
2,000	-5	5.20	5.12	5.03	4.95	4.87	4.78	4.67	4.55	4.42	4.25	3.89	4.44	4.500
2,000	-4	4.41	4.38	4.34	4.30	4.27	4.23	4.18	4.14	4.09	4.01	3.89	4.09	4.149
2,000	-3	4.16	4.13	4.11	4.09	4.07	4.04	4.02	4.00	3.97	3.94	3.89	3.97	4.033
2,000	-2	4.08	4.06	4.04	4.03	4.01	3.99	3.97	3.95	3.93	3.91	3.89	3.94	3.996
2,000	-1	4.05	4.04	4.02	4.01	3.99	3.97	3.96	3.94	3.92	3.91	3.89	3.92	3.985
2,000	0	4.05	4.00	4.01	4.00	3.98	3.97	3.95	3.94	3.92	3.90	3.89	3.92	3.982
2,500	-6	25.55	23.62	21.65	19.67	17.61	15.47	13.30	11.10	8.79	6.43	3.98	9.06	
2,500	-5	16.96	13.55	15.12	14.14	13.07	11.93	10.71	9.39	7.88	6.14	3.98	8.06	
2,500	-4	9.32	9.01	8.68	8.34	7.97	7.55	7.10	6.61	6.02	5.27	3.98	6.09	
2,500	-3	5.90	5.79	5.67	5.56	5.42	5.29	5.13	4.97	4.77	4.51	3.98	4.79	
2,500	-2	4.69	4.65	4.61	4.56	4.51	4.46	4.39	4.33	4.26	4.17	3.98	4.27	
2,500	-1	4.31	4.28	4.26	4.24	4.21	4.18	4.14	4.12	4.08	4.05	3.98	4.09	
2,500	0	4.17	4.16	4.14	4.13	4.10	4.09	4.07	4.05	4.03	4.01	3.98	4.03	
3,000	-6	24.84	22.79	20.72	18.66	16.59	14.51	12.44	10.36	8.28	6.20	4.12	8.52	8.521
3,000	-5	24.25	22.29	20.32	18.33	16.33	14.33	12.30	10.27	8.21	6.15	4.07	8.45	8.424
3,000	-4	20.51	19.13	17.71	16.24	14.72	13.14	11.50	9.77	7.98	6.07	4.05	8.19	8.121
3,000	-3	12.76	12.20	11.60	10.97	10.30	9.57	8.78	7.90	6.90	5.69	4.05	7.02	6.984
3,000	-2	7.43	7.24	7.03	6.82	6.58	6.34	6.05	5.75	5.38	4.91	4.04	5.43	5.514
3,000	-1	5.26	5.19	5.12	5.04	4.96	4.88	4.77	4.67	4.54	4.39	4.04	4.55	4.722
3,000	0	4.53	4.50	4.47	4.42	4.39	4.35	4.32	4.27	4.23	4.17	4.04	4.24	4.424
3,500	-6	22.06	20.57	18.90	17.21	15.50	13.77	12.04	10.31	8.58	6.83	5.09	8.78	
3,500	-5	22.03	20.33	18.58	16.82	15.07	13.30	11.52	9.75	7.97	6.19	4.41	8.18	
3,500	-4	21.70	20.02	18.29	16.55	14.81	13.06	11.30	9.54	7.76	5.98	4.19	7.97	
3,500	-3	19.41	18.07	16.69	15.28	13.83	12.34	10.80	9.21	7.58	5.89	4.13	7.77	
3,500	-2	13.07	12.45	11.82	11.14	10.41	9.64	8.80	7.89	6.85	5.64	4.11	6.98	
3,500	-1	7.75	7.54	7.31	7.07	6.82	6.54	6.25	5.69	5.51	4.99	4.10	5.55	
3,500	0	5.42	5.34	5.26	5.18	5.09	5.00	4.89	4.78	4.64	4.46	4.10	4.65	
4,000	-6	19.92	19.82	19.08	18.15	17.13	16.04	14.85	13.74	12.54	11.31	10.07	12.68	12.754
4,000	-5	19.92	18.94	17.63	16.27	14.86	13.45	12.00	10.56	9.10	7.64	6.17	9.27	9.310
4,000	-4	19.89	18.51	17.03	15.53	14.01	12.49	10.96	9.42	7.88	6.34	4.79	8.04	8.073
4,000	-3	19.56	18.11	16.62	15.11	13.61	12.08	10.55	9.01	7.47	5.92	4.35	7.65	7.623
4,000	-2	17.23	16.12	14.96	13.78	12.55	11.29	9.98	8.62	7.21	5.74	4.20	7.38	7.277
4,000	-1	11.50	11.02	10.50	9.96	9.38	8.75	8.08	7.32	6.48	5.47	4.16	6.58	6.476
4,000	0	7.08	6.91	6.74	6.55	6.35	6.12	5.88	5.61	5.29	4.89	4.15	5.33	5.432
4,500	-6	18.26	19.26	19.99	20.50	20.86	21.09	21.23	21.28	21.26	21.18	21.04	21.26	
4,500	-5	18.26	18.53	18.21	17.64	16.97	16.20	15.38	14.53	13.62	12.69	11.74	13.73	
4,500	-4	18.26	17.60	16.56	15.43	14.27	13.07	11.86	10.63	9.38	8.13	6.86	9.52	
4,500	-3	18.20	17.06	15.79	14.48	13.16	11.82	10.48	9.13	7.78	6.42	5.05	7.93	
4,500	-2	17.64	16.43	15.17	13.87	12.57	11.25	9.27	8.57	7.22	5.84	4.46	7.37	
4,500	-1	14.55	13.74	12.89	11.99	11.07	10.10	9.08	7.99	6.84	5.61	4.26	6.99	
4,500	0	9.32	9.00	8.66	8.30	7.91	7.50	7.05	6.55	5.96	5.23	4.20	6.03	

L-179

TABLE VIII.- DIMENSIONLESS RATIO $\frac{H}{RT}$ OF ENTHALPY TO TEMPERATURE, ACCORDING TO EQUATION (66) - Concluded

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	Values of $\frac{H}{RT}$ for -												
		α												
		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From reference 2)
		ρ_0												
		1.4284×10^{-3}	1.4106×10^{-3}	1.3928×10^{-3}	1.3750×10^{-3}	1.3573×10^{-3}	1.3395×10^{-3}	1.3217×10^{-3}	1.3039×10^{-3}	1.2861×10^{-3}	1.2683×10^{-3}	1.2505×10^{-3}	1.2882×10^{-3}	
5,000	-6	16.94	18.00	19.03	20.02	21.00	21.94	22.86	23.75	24.61	25.46	26.28	24.51	24.618
5,000	-5	16.94	17.87	18.58	19.12	19.52	19.81	20.03	20.16	20.22	20.24	20.20	20.22	20.351
5,000	-4	16.93	17.26	17.03	16.60	16.05	15.42	14.73	14.00	13.24	12.44	11.62	13.33	13.427
5,000	-3	16.92	16.39	15.49	14.50	13.47	12.41	11.33	10.22	9.12	8.00	6.87	9.24	9.296
5,000	-2	16.78	15.80	14.67	13.50	12.33	11.14	9.95	8.74	7.52	6.31	5.08	7.66	7.665
5,000	-1	15.58	14.64	13.61	12.56	11.49	10.39	9.27	8.12	6.94	5.73	4.48	7.08	6.980
5,000	0	11.47	10.98	10.44	9.87	9.28	8.64	7.95	7.20	6.38	5.42	4.27	6.48	6.314
5,500	-6	15.85	16.83	17.80	18.77	19.73	20.69	21.65	22.61	23.55	24.50	25.44	23.44	23.695
5,500	-5	15.85	16.81	17.73	18.62	19.48	20.30	21.10	21.86	22.60	23.32	24.00	22.52	22.693
5,500	-4	15.85	16.66	17.23	17.63	17.89	18.05	18.14	18.16	18.11	18.01	17.88	18.12	18.292
5,500	-3	15.84	16.04	15.74	15.27	14.68	14.05	13.35	12.63	11.87	11.10	10.29	11.96	12.077
5,500	-2	15.80	15.24	14.40	13.46	12.50	11.51	10.51	9.49	8.46	7.42	6.38	8.58	8.622
5,500	-1	15.36	14.50	13.52	12.50	11.45	10.40	9.34	8.25	7.16	6.05	4.93	7.29	7.245
5,500	0	12.87	12.25	11.56	10.82	10.06	9.26	8.41	7.52	6.57	5.56	4.45	6.68	6.520
6,000	-6	14.94	15.84	17.40	17.63	18.53	19.42	20.31	21.21	22.10	22.99	23.88	22.00	22.632
6,000	-5	14.94	15.84	16.73	17.61	18.49	19.36	20.21	21.07	21.92	22.77	23.60	21.82	22.148
6,000	-4	14.94	15.81	16.61	17.37	18.08	18.73	19.35	19.93	20.48	20.98	21.46	20.42	20.664
6,000	-3	14.94	15.60	15.93	16.07	16.09	16.01	15.86	15.65	15.39	15.09	14.75	15.42	15.646
6,000	-2	14.92	14.91	14.44	13.86	13.19	12.49	11.73	10.97	10.18	9.37	8.55	10.27	10.392
6,000	-1	14.74	14.15	13.31	12.42	11.51	10.58	9.62	8.67	7.70	6.71	5.72	7.81	7.825
6,000	0	13.43	12.76	11.99	11.19	10.36	9.50	8.61	7.69	6.73	5.75	4.72	6.86	6.736
6,500	-5	14.18	15.01	15.83	16.66	17.48	18.30	19.12	19.94	20.76	21.58	22.39	20.66	21.324
6,500	-4	14.18	15.00	15.81	16.60	17.37	18.14	18.90	19.64	20.38	21.09	21.80	20.30	20.681
6,500	-3	14.18	14.94	15.59	16.14	16.61	17.02	17.35	17.65	17.90	18.10	18.27	17.87	18.208
6,500	-2	14.17	14.58	14.59	14.43	14.16	13.81	13.40	12.96	12.48	11.98	11.44	12.54	12.785
6,500	-1	14.09	13.83	13.22	12.54	11.81	11.04	10.25	9.45	8.63	7.80	6.96	8.72	8.820
6,500	0	13.40	12.82	12.07	11.29	10.48	9.64	8.78	7.91	7.01	6.10	5.16	7.12	7.065
7,000	-4	13.52	14.29	15.05	15.81	16.57	17.32	18.07	18.81	19.54	20.28	21.03	19.46	20.113
7,000	-3	13.52	14.27	14.99	15.66	16.31	16.93	17.52	18.08	18.62	19.13	19.63	18.56	19.017
7,000	-2	13.52	14.13	14.51	14.75	14.88	14.93	14.90	14.83	14.71	14.65	14.37	14.72	15.122
7,000	-1	13.48	13.58	13.26	12.83	12.33	11.77	11.18	10.57	9.92	9.27	8.61	10.00	10.217
7,000	0	13.10	12.69	12.04	11.33	10.60	9.84	9.06	8.27	7.46	6.63	5.79	7.55	7.575
8,000	-3	12.46	13.13	13.79	14.45	15.11	15.76	16.40	17.05	17.69	18.32	18.94	17.66	18.537
8,000	-2	12.45	13.13	13.71	14.28	14.82	15.32	15.77	16.22	16.63	17.02	17.38	16.58	17.258
8,000	-1	12.44	12.94	13.20	13.31	13.34	13.28	13.18	13.02	12.83	12.61	12.36	12.86	13.411
8,000	0	12.31	12.33	12.00	11.58	11.09	10.58	10.01	9.44	8.86	8.24	7.62	8.92	9.179
9,000	-2	11.63	12.22	12.81	13.39	13.95	14.51	15.06	15.60	16.14	16.66	17.19	16.08	17.150
9,000	-1	11.62	12.18	12.65	13.08	13.45	13.77	14.04	14.29	14.50	14.66	14.82	14.47	15.338
9,000	0	11.57	11.90	11.95	11.86	11.70	11.47	11.21	10.91	10.58	10.23	9.86	10.62	11.245
10,000	-1	10.96	11.49	12.00	12.47	12.94	13.39	13.81	14.22	14.61	14.98	15.35	14.57	15.728
10,000	0	10.94	11.38	11.68	11.87	11.99	12.05	12.06	12.04	11.99	11.89	11.79	11.99	12.990

L-179

TABLE IX.- DIMENSIONLESS ENTROPY S/R ACCORDING TO EQUATION (68)

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	Values of S/R for -												
		α												
		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From reference 2)
		ρ_0												
		1.4284×10^{-3}	1.4106×10^{-3}	1.3928×10^{-3}	1.3750×10^{-3}	1.3573×10^{-3}	1.3395×10^{-3}	1.3217×10^{-3}	1.3039×10^{-3}	1.2861×10^{-3}	1.2683×10^{-3}	1.2505×10^{-3}	1.2882×10^{-3}	
1,000	-6	41.79	41.93	41.92	41.84	41.71	41.55	41.35	41.09	40.87	40.53	39.93	40.91	
1,000	-5	39.48	39.62	39.61	39.54	39.41	39.25	39.05	38.79	38.57	38.23	37.61	38.61	
1,000	-4	37.18	37.32	37.31	37.24	37.10	36.95	36.75	36.48	36.27	35.91	35.33	36.30	
1,000	-3	34.88	35.02	35.01	34.94	34.80	34.65	34.44	34.18	33.97	33.62	33.03	34.00	
1,000	-2	32.58	32.72	32.71	32.63	32.50	32.34	32.14	31.88	31.66	31.32	30.72	31.70	
1,000	-1	30.27	30.41	30.40	30.33	30.19	30.04	29.84	29.58	29.36	29.02	28.42	29.40	
1,000	0	27.97	28.11	28.10	28.03	27.89	27.74	27.53	27.27	27.06	26.72	25.12	27.09	
1,500	-6	43.14	43.27	43.25	43.17	43.03	42.86	42.64	42.37	42.08	41.60	41.15	42.11	
1,500	-5	40.82	40.95	40.93	40.84	40.71	40.48	40.32	40.05	39.76	39.38	38.83	39.80	
1,500	-4	38.51	38.64	38.62	38.54	38.40	38.23	38.02	37.75	37.46	37.08	36.55	37.49	
1,500	-3	36.20	36.33	36.32	36.23	36.10	35.93	35.71	35.44	35.06	34.77	34.24	35.19	
1,500	-2	33.90	34.02	34.01	33.89	33.80	33.62	33.41	33.14	32.85	32.47	31.94	32.89	
1,500	-1	31.60	31.73	31.71	31.74	31.49	31.32	30.89	30.84	30.55	30.17	29.64	30.59	
1,500	0	29.29	29.42	29.41	29.32	29.19	29.02	28.80	28.54	28.25	27.86	27.34	28.28	
2,000	-6	47.69	47.62	47.39	47.08	46.71	46.28	45.77	45.18	44.50	43.64	42.10	44.43	44.676
2,000	-5	42.96	43.03	42.94	42.78	42.57	42.32	42.01	41.63	41.22	40.69	39.80	41.11	41.354
2,000	-4	39.85	39.96	39.92	39.81	39.65	39.45	39.20	38.90	38.56	38.14	37.50	38.44	38.689
2,000	-3	37.29	37.41	37.38	37.29	37.15	36.96	36.74	36.45	36.15	35.76	35.20	36.02	36.267
2,000	-2	34.91	35.03	35.01	34.92	34.78	34.60	34.38	34.10	33.81	33.43	32.89	33.68	33.926
2,000	-1	32.58	32.71	32.68	32.59	32.46	32.28	32.06	31.79	31.49	31.12	30.59	31.37	31.612
2,000	0	30.27	30.39	30.37	30.28	30.15	29.97	29.75	29.48	29.19	28.81	28.29	29.06	29.305
2,500	-6	68.31	66.41	64.29	62.05	59.72	57.27	54.70	52.02	49.22	46.22	42.85	49.31	
2,500	-5	55.57	55.33	54.33	53.22	51.99	50.64	49.14	47.48	45.62	43.42	40.55	45.61	
2,500	-4	45.68	45.50	45.14	44.71	44.20	43.61	42.93	42.16	41.27	40.13	38.24	41.14	
2,500	-3	39.79	39.82	39.69	39.49	39.24	38.93	38.56	38.12	37.63	37.01	35.94	37.46	
2,500	-2	36.23	36.33	36.21	36.15	35.97	35.75	35.48	35.16	34.70	34.35	33.64	34.61	
2,500	-1	33.52	33.64	33.60	33.50	33.35	33.16	32.93	32.63	32.32	31.92	31.33	32.12	
2,500	0	31.09	31.21	31.18	31.09	30.95	30.77	30.54	30.26	29.96	29.58	29.03	29.63	
3,000	-6	71.82	69.43	66.87	64.23	61.52	58.76	55.92	53.01	50.04	46.94	43.54	50.39	50.407
3,000	-5	66.69	64.61	62.36	60.03	57.61	55.13	52.57	49.92	47.20	44.35	41.19	47.53	47.526
3,000	-4	58.75	57.42	55.89	54.24	52.48	50.61	48.62	46.49	44.23	41.74	38.87	44.50	44.469
3,000	-3	47.68	47.23	46.59	45.85	45.02	44.09	43.05	41.86	40.65	38.87	36.56	40.69	40.702
3,000	-2	39.69	39.62	39.40	39.09	38.72	38.29	37.80	37.18	36.54	35.69	34.25	36.63	36.782
3,000	-1	35.10	35.17	35.08	34.92	34.71	34.45	34.14	33.76	33.35	32.82	31.95	33.40	33.637
3,000	0	32.02	32.13	32.08	31.97	31.81	31.60	31.36	31.05	30.71	30.29	29.65	30.76	31.021
3,500	-6	72.34	70.24	67.80	65.25	62.62	59.92	57.16	54.31	51.39	48.02	45.01	51.74	
3,500	-5	67.71	65.63	63.33	60.95	58.49	55.97	53.40	50.73	48.01	45.16	42.02	48.33	
3,500	-4	62.81	60.96	58.91	56.77	54.56	51.90	49.95	47.53	45.04	43.41	39.49	45.33	
3,500	-3	56.20	54.87	53.36	51.71	50.01	47.81	46.28	44.24	42.10	39.78	37.12	42.36	
3,500	-2	46.33	45.82	45.12	44.32	43.43	42.06	41.34	40.09	38.70	37.03	34.79	38.87	
3,500	-1	38.24	38.15	37.91	37.58	37.18	36.34	38.81	35.57	34.86	33.96	32.48	34.95	
3,500	0	33.46	33.52	33.42	33.25	33.03	32.38	32.45	32.06	31.62	31.08	30.18	31.68	
4,000	-6	72.74	71.88	70.17	68.20	66.06	62.83	61.39	58.94	56.37	53.65	50.61	56.68	56.782
4,000	-5	68.13	66.57	64.52	62.32	60.02	57.64	55.19	52.65	50.04	47.29	44.25	50.34	50.410
4,000	-4	63.50	61.76	59.75	57.64	55.45	53.20	50.88	48.47	46.01	43.41	40.53	46.29	46.341
4,000	-3	58.60	57.01	55.21	53.32	51.37	49.34	47.25	45.06	42.82	40.44	37.76	43.08	43.100
4,000	-2	52.00	50.90	49.63	48.07	46.76	45.18	43.51	41.71	39.81	37.74	35.31	40.04	40.005
4,000	-1	42.84	42.75	41.88	41.22	40.47	39.63	38.69	37.62	36.42	34.96	32.96	36.57	36.574
4,000	0	35.69	35.64	35.44	35.16	34.81	34.41	33.94	33.38	32.75	31.96	30.64	32.84	33.074
4,500	-6	73.10	73.36	73.07	72.47	71.63	70.60	69.40	68.02	66.52	64.81	62.76	66.70	
4,500	-5	68.49	68.10	66.88	65.36	63.64	61.79	59.81	57.70	55.50	53.14	50.46	55.76	
4,500	-4	63.88	62.72	61.00	59.11	57.12	55.04	52.88	50.61	48.29	45.44	43.05	48.56	
4,500	-3	59.22	57.79	56.05	54.20	52.28	50.28	48.21	46.06	43.85	41.50	38.86	44.11	
4,500	-2	54.14	52.84	51.32	49.71	48.02	46.26	43.73	42.51	40.51	38.37	35.94	40.75	
4,500	-1	46.97	46.21	45.26	44.21	43.05	42.50	40.46	38.98	37.36	35.60	33.44	37.60	
4,500	0	38.56	38.34	37.96	37.50	36.95	36.34	35.64	34.82	33.90	32.75	31.07	34.02	

L-179

TABLE IX.- DIMENSIONLESS ENTROPY S/R ACCORDING TO EQUATION (68) - Concluded

T, °K	$\log_{10} \frac{\rho}{\rho_0}$	Values of S/R for -												
		α												
		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.78847	0.78847 (From reference 2)
		ρ_0												
		1.4284×10^{-3}	1.4106×10^{-3}	1.3928×10^{-3}	1.3750×10^{-3}	1.3573×10^{-3}	1.3395×10^{-3}	1.3217×10^{-3}	1.3039×10^{-3}	1.2861×10^{-3}	1.2683×10^{-3}	1.2505×10^{-3}	1.2882×10^{-3}	
5,000	-6	73.40	73.84	73.95	73.90	73.72	73.44	73.05	72.54	71.95	71.18	70.09	72.02	72.171
5,000	-5	68.80	69.12	68.93	68.46	67.78	66.92	65.90	64.71	63.40	61.90	60.06	63.57	63.735
5,000	-4	63.40	63.97	62.97	61.67	60.19	58.56	56.81	54.94	52.98	50.85	48.40	53.21	53.351
5,000	-3	59.58	58.65	57.17	55.52	53.76	51.81	49.98	47.96	45.87	43.63	41.10	46.12	46.201
5,000	-2	54.85	53.67	52.18	50.58	48.90	47.15	45.32	43.41	41.44	39.33	36.93	41.68	41.720
5,000	-1	49.25	48.29	47.10	45.81	44.43	42.98	41.44	39.79	38.07	36.20	34.00	38.28	38.267
5,000	0	41.44	41.03	40.43	39.74	38.95	38.08	37.11	36.02	34.81	33.37	31.50	34.96	34.948
5,500	-6	73.69	74.14	74.28	74.29	74.20	74.02	73.77	73.41	72.97	72.39	71.50	73.03	73.337
5,500	-5	69.08	69.51	69.61	69.56	69.37	69.05	68.67	68.13	67.51	66.71	65.60	67.59	67.815
5,500	-4	64.48	64.78	64.56	64.06	63.35	62.47	61.44	60.24	58.97	57.44	55.61	59.09	59.314
5,500	-3	59.87	59.63	58.67	57.45	56.06	54.54	52.92	51.16	49.33	47.34	45.04	49.55	49.710
5,500	-2	55.23	54.40	53.08	51.61	50.05	48.39	46.68	44.84	42.95	40.92	38.59	43.18	43.271
5,500	-1	50.26	49.31	48.08	46.74	45.30	41.35	42.24	40.56	38.83	36.95	34.78	39.03	39.068
5,500	0	43.68	43.11	42.31	41.41	40.42	39.34	38.18	36.88	35.48	33.91	31.97	35.65	35.631
6,000	-6	73.95	74.40	74.55	74.56	74.49	74.32	74.08	73.73	73.32	72.77	71.91	73.38	74.092
6,000	-5	69.34	69.79	69.93	69.89	69.84	69.66	69.38	69.01	68.56	67.96	67.06	68.61	69.012
6,000	-4	64.74	65.16	65.23	65.12	64.61	64.50	64.01	63.38	62.66	61.76	60.54	62.75	63.069
6,000	-3	60.13	60.36	60.01	59.37	58.53	57.53	56.38	55.09	53.69	52.12	50.22	53.86	54.139
6,000	-2	55.51	55.17	54.19	52.98	51.64	50.19	48.64	46.99	45.26	43.38	41.19	45.46	45.639
6,000	-1	50.76	50.01	48.85	47.55	46.17	44.72	43.18	41.55	39.86	38.57	35.90	40.06	40.153
6,000	0	45.11	44.46	43.55	42.52	41.41	40.22	38.95	37.57	36.11	34.48	32.54	36.78	36.295
6,500	-5	69.58	70.03	70.16	70.17	69.92	69.77	69.55	69.35	68.93	68.37	67.51	68.98	69.753
6,500	-4	64.98	65.42	65.54	65.53	65.22	65.03	64.75	64.48	63.99	63.34	62.38	64.05	64.535
6,500	-3	60.37	60.76	60.74	60.52	59.95	59.44	58.80	58.13	57.22	56.12	54.69	57.33	57.746
6,500	-2	55.76	57.97	55.29	54.46	53.28	52.14	50.93	48.68	48.20	46.56	44.60	48.37	48.687
6,500	-1	51.09	50.64	49.65	48.49	47.04	45.71	44.30	42.88	41.27	39.52	37.47	41.47	41.640
6,500	0	45.95	45.33	44.40	43.34	42.02	40.83	39.55	38.28	36.80	35.19	33.27	36.98	37.051
7,000	-4	64.87	65.35	65.79	65.80	65.72	65.54	65.28	64.97	64.86	63.90	63.82	64.54	65.306
7,000	-3	60.26	60.73	61.13	61.07	60.89	60.59	60.19	59.73	59.06	58.29	57.19	59.14	59.702
7,000	-2	55.66	56.00	56.11	55.67	55.04	54.27	53.35	52.36	51.15	49.82	48.16	51.29	51.772
7,000	-1	51.06	50.93	50.49	49.54	48.45	47.25	46.05	44.67	43.06	41.43	39.50	43.24	43.542
7,000	0	46.54	45.48	45.09	44.06	42.95	41.75	40.47	39.15	37.65	36.07	34.18	37.83	37.969
8,000	-3	60.99	61.44	61.58	61.59	61.51	61.32	61.06	60.71	60.24	59.67	58.78	60.31	61.411
8,000	-2	56.39	56.82	56.91	56.84	56.64	56.33	55.91	55.39	54.74	53.95	52.83	54.83	55.646
8,000	-1	51.77	52.07	51.87	51.42	50.80	50.05	49.16	48.16	47.04	45.77	44.17	47.18	47.840
8,000	0	47.07	46.99	46.55	45.52	44.57	43.53	42.39	41.16	39.83	38.37	36.61	39.99	40.350
9,000	-2	56.74	57.19	57.32	57.33	57.22	57.03	56.75	56.37	55.90	55.28	54.37	55.36	57.276
9,000	-1	52.13	52.55	52.59	52.47	52.20	51.80	51.29	50.67	49.93	49.02	47.81	50.02	51.088
9,000	0	47.49	47.72	47.42	46.89	46.22	45.41	44.50	43.49	42.36	41.09	39.52	42.50	43.290
10,000	-1	52.45	52.89	53.01	52.98	52.85	52.61	52.27	51.84	51.30	50.61	49.61	51.36	52.823
10,000	0	47.83	48.20	48.15	47.89	47.47	46.93	46.28	45.51	44.62	43.58	42.23	44.73	45.960