NASA CR-72348
GA-8244

OPTICAL CONSTANTS OF URANIUM PLASMA

by

D. E. Parks, G. Lane, J. C. Stewart,
and S. Peyton

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NAS 3-7961

Gulf General Atomic
Incorporated

Requests for copies of this report should be referred to

National Aeronautics and Space Administration
Office of Scientific and Technical Information
Attention: AFSS-A
Washington, D. C. 20546

NASA CR-72348
GA-8244

FINAL REPORT

OPTICAL CONSTANTS OF URANIUM PLASMA

Work done by:

G. Lane
A. Levels
G. Marks
D. E. Parks
S. Peyton
M. Rotenberg
J. C. Stewart

Report written by:

D. E. Parks
G. Lane
J. C. Stewart
S. Peyton

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

February 2, 1968

CONTRACT NAS 3-7961

Technical Management
NASA Lewis Research Center
Cleveland, Ohio
Nuclear Systems Division
R. W. Patch, Project Manager
Advanced Systems Division
John C. Liwosz

Gulf General Atomic
Incorporated
P.O. Box 608, San Diego, California 92112

The HALIDE computer code is described herein as it existed on January 31, 1968. The code, in its presented form, has been applied successfully by Gulf General Atomic to the kind of problems discussed later in this report. Gulf General Atomic has exercised due care in preparation, but does not warrant the merchantability, accuracy, and completeness of the code or of its description contained herein. The complexity of this kind of program precludes any guarantee to that effect. Therefore, any user must make his own determination of the suitability of the code for any specific use, and of the validity of the information produced by use of the code.

ABSTRACT

Thermodynamic and optical properties of a uranium plasma are calculated for conditions that obtain in proposed gaseous-core nuclear rockets. As a quantitative basis for calculations, we begin with the relativistic wave-mechanical description of a single electron moving in a spherically symmetric potential. The potential is a modified Thomas-Fermi potential containing an arbitrary parameter whose value we determine by calibration against one-electron binding energies previously calculated by a relativistic, self-consistent-field method.

From the corresponding single-particle wave functions, we calculate oscillator strengths and estimate the many-electron properties of ions that are relevant to thermodynamic and optical properties. Particular emphasis is given to the often significant effects associated with the rich energy level and line spectra that appear in the spectroscopy of ions having several electrons in partially filled shells. Pressure ionization is treated in a manner that is approximately valid for nondegenerate gases for any ratio of Debye length to ion sphere radius and that satisfies the requirements of thermodynamic consistency. Specific results for composition, thermodynamic functions, and local and overall Planck and Rosseland mean opacities of uranium are given for the temperature range from 5000°K to 110,000°K and the pressure range from 100 to 1000 atmospheres. Finally, we compare the theoretical opacity at 5100°K and 3.58×10^{-4} atm with that inferred from the measured emission from an arc containing uranium.

CONTENTS

FIGURES

TABLES

TABLES (continued)

NOMENCLATURE

Symbol	
a	Eq. (110)
a_0	Bohr radius
a_{1v}, a_{2v}, a_{3v}, b_{1v} b_{2v}, b_{3v}	coefficients in the simultaneous equations (A-61), (A-62) which determine $\bar{z}_v$ and s_v; p. 159
$a_{1\theta}$, $a_{2\theta}$, $a_{3\theta}$, $b_{1\theta}$, $b_{2\theta}$, $b_{3\theta}$	coefficients in the simultaneous equations (A-55) which determine $\bar{z}_\theta$ and s_θ; p. 158
$a_\alpha (a_\beta, a_j); (\alpha, \beta, j = 1, 2, \ldots)$	Debye charging parameter for α^{th} (β^{th}, j^{th}) ion in plasma
$B(u)$	the Planck black body function, $B(u) = \frac{15}{\pi^4} \frac{u^3}{e^4 - 1}$
C_p	specific heat at constant pressure; Eq. (A-41)
C_v	specific heat at constant volume; Eq. (A-40)
c	speed of light
D	the Gaussian width of a line cluster in units of energy divided by $k_B T$
D_{ff}	a quantity appearing in the Raiser approximation for the continuous opacity, Eq. (D-8)
E	internal energy of plasma; Eq (A-21)
E_0	lowest energy in a given subconfiguration
$E_a = E_{as}$	energy for which the asymptotic quantum defect has been tabulated in Table 23
E_{ex}	contribution of electronic excitation to the internal energy

$E_{ex,\,k}$	electronic excitation energy of an ion of species k measured from a zero energy with the ion in the ground state
$E_{ex,\,k,\,\theta}$	$(\partial E_{ex,\,k}/\partial \Theta)_v$
$E_{ex,\,v}$	$(\partial E_{ex}/\partial v)_\theta$
E_{ion}	ionization energy
E_{kin}	contribution of translational motion to internal energy
$E_k(i, K)$	energy of ion of species k in the quantum state i of the subconfiguration K
$E_k(0, 0)$	ground state energy of ion of species k
$E_k(i)$	energy of a free ion of k^{th} species in a quantum state i ($k = 0, 1, \ldots$); the zero of energy is for a state in which all of the electrons are at rest at infinity
E_p	modification of internal energy arising from Coulomb interactions between charged particles
$E_{p,\,\theta}$	$(\partial E_p/\partial \Theta)_v$
E_θ	$(\partial E/\partial \Theta)_v$
$E(K), E(\{N_i\})$	average energy of a subconfiguration $K = \{N_i\}$ in an ion; the zero of energy is for all electrons at rest at infinity; Eq. (11)
ERKROS	the relative contribution of the interval $u_{max} \leq u < \infty$ is almost certainly less than ERKROS
e	electronic charge

F	Helmholtz free energy
F	$\overline{J}/\overline{z}$; Eq. (A-44)
F_0	the Helmholtz energy exclusive of F_p; Eq. (A-33)
F_p	contribution of plasma effects to the Helmholtz free energy
$F_{ij}^{(k)}$	a direct Slater integral; Eq. (15)
$F(E)$	fraction of states per unit energy at energy E in a given subconfiguration; Eq. (20)
$F_K(E)$	the function F(E) (Eq. (20)) for the subconfiguration K
$F(\tau_0)$	Araki's function; Eq. (C-11)
F, I	factors occurring in the Bates-Damgaard formula for bound-bound radial matrix elements; Eqs. (B1-B3)
F_v	$(\partial F_v/\partial v)_\theta$; Eq. (A-28)
f	a quantity used in the calculation of the temperature derivative of the plasma contribution to the specific internal energy; Eq. (A-45)
f_i	average value of the sum of the kinetic energy of an electron in shell i and its interaction energy with the central field created by the nuclear charge and electrons in I-orbitals
$f_k^{(A)}$	the number of ions of species k in a subconfiguration K having no E electrors divided by the total number of nuclei; Eq. (81)
$f_k^{(B)}$	the number of ions of species k consisting of the subconfiguration K containing no E electrons and one E electron; Eq. (82)
$f(E(s, K))$	an arbitrary function of the energy associated with the quantum state s of an ion in the subconfiguration K

$f(J)$	angular momentum distribution function
$f(r)$	large component of Dirac radial wave function
$G_{ij}^{(k)}$	exchange Slater integral; Eq. (16)
$G(x)$	a function involved in the calculation of F_p; Eq. (A-36)
$G = G_{\ell\ell'}$ $\gamma = \gamma_{\ell\ell'}$ E ϕ $\psi = \psi_{\ell\ell'}$ $x = x_{\ell\ell'}$ $\alpha = \alpha_{\ell\ell'}$ $\beta = \beta_{\ell\ell'}$	These quantities appear in the equations relating bound-free cross sections and the contents of the Burgess-Seaton tables; p. 170
$g_k(i)$	degeneracy of atomic state i in k^{th} ion species
$g_k(i)$	degeneracy of the i^{th} shell in the k^{th} ion
$g(r)$	small component of Dirac radial wave function
g_θ	a quantity used in the calculation of the temperature derivative of the plasma contribution to the specific internal energy; Eq. (A-45)
g_v	a function used in the calculation of the volume derivative of the plasma contribution to the specific internal energy; Eq. (A-50)
$H(a, x)$	the Voigt function
$\overline{H}(a, x)$	the Voigt function normalized to unity at the cluster center; Eq. (111)
$H(s)$	a function appearing in the study of pressure lowering of ionization potentials; Eq. (A-7)
$H(x, y)$	Eq. (A-20)

h	Planck's constant
h_k	the fraction of ions of species k having an E electron; Eq. (83)
$\hbar$	$= h/2\pi$
I_d	the ionization potential of the dominant ion species
I_k $(k = 0, 1, \ldots)$	ionization potential of a free ion of species k
I_k	ionization potential of ion of species k; (Eq. 65)
I'_k	ionization potential of a plasma ion of species k
I_∞, J, K	coefficients in the interpolation formula (B-3) for I; Eqs. (B4-B6)
I-electron (shell) M-electron (shell) E-electron (shell)	defined on p. 16
J	angular momentum quantum number
J_{av}	average value of J in a subconfiguration
J(z)	average potential in units of ℋ at the position of an ion with ionic charge $z = z'-1$ resulting from all other charged particles in the plasma; Eq. (45)
$\overline{J} = \overline{J}(\overline{z})$	average potential in units of ℋ at the position of a fictitious ion having an average charge $\overline{z}$
$J(a_\beta)$ $S(a_\beta)$	auxiliary functions used in the study of plasma effects on statistical mechanical properties of the plasma
j	single-electron total angular momentum quantum number

K	subconfiguration label
K(z)	$ze^2/D\circledR$; Eq. (47)
$\overline{K}$	$\overline{z}e^2/D\circledR$; Eq. (52)
k	wave number of photoelectron in atomic units
k = z' - 1	ionic charge in units of electronic charge
k_B	Boltzmann's constant
k_R	the overall Rosseland mean opacity; Eq. (D-2)
$L(\tau_0)/2$	the Ladenburg-Reiche function; Eq. (C-9)
ℓ	orbital quantum number
M	atomic mass of element under consideration
M	matrix element for bound-bound transitions; Eq. (90)
M_k	degeneracy of k^{th} shell
m	electronic mass
m_k	the value that the parameter m in F(E) (Eq. (20)) takes in an ion of species k; m_k is assumed to be independent of the subconfiguration K
N_0	Avogadro's number
N_i	number of electrons in shell i
N(in Sec. 3.1)	total number of plasma ions of all nuclei in the plasma
N_{Lev}	number of energy levels in a subconfiguration
$N_{Lin}(N)$	number of lines in a transition array
$\{N_i\}$	set of occupation numbers in a subconfiguration

n	principal quantum number
n, n'	principal quantum numbers for the initial and final electron states, respectively. Except in discussing transitions, we use n to denote the principal quantum number of any one electron state
$n^*, n^{*'}$	n^* and $n^{*'}$ are the effective principal quantum numbers for the initial and final single electron states, respectively, which occur when a photon is absorbed. Except in discussing transitions, where a pair of states is involved, we use n^* to denote the effective principal quantum number of any single electron state
$n^*_<$ $(n^*_>)$	the lesser (greater) of $n^*(i)$ and $n^*(k)$
$n_{as}(z', I)$	for $n > n_{as}(k, I)$, we find oscillator strengths by extrapolation of the bound-free strengths
$n_c(z', I)$	If $n > n_c(k, I)$ the electron is an E-electron
n_e	number of free electrons in plasma
$n'_e(z', I)$	the principal quantum number of the first (lowest n) possibly empty shell with angular momentum index I in an ion of species $k = z' - 1$
$n_F(z', I)$	shells with $n \leq n_F(k, I)$ are always filled
n_k	number of ions of k^{th} species in plasma
$\bar{n}_k$	one-electron states with principal quantum number n greater than $\bar{n}_k$ (for hydrogenic states) or $\bar{n}_k(i)$ $(i = 1 \ldots 5$, i.e., $s_{\frac{1}{2}}$, $p_{\frac{1}{2}}$, $p_{\frac{3}{2}}$, d, f states) are pressure ionized
$n_{Lin}(J, j, j')$	the number of lines in the array $\ell_j \rightarrow \ell' j'$ given that the angular momentum J of the electrons not participating in the transition does not change; p. 75

$n_{min,\,k}^{(i)}$	the smallest principal quantum that an E-electron may have in the one-electron angular momentum state i in an ion of species k
$n_{min}(z', I)$	the smallest principal quantum number that is considered for an electron in orbital state I in an ion of species k = z'-1
$n_{0,\,k}^2$	Eq. (A-13)
P	pressure
P_{kin}	the part of the pressure arising from free translational motion
P_P	the modification of the pressure arising from Coulomb interactions between charged particles.
P = P(r)	single-electron radial wave function
P_i	single-electron radial wave function associated with state i
$P_j(u-u_{0j})$	the distribution function for the position of line centers in the j^{th} line cluster
$P(u_1-u_0)$	the distribution function for the position of line centers in a line cluster
p_k (k = 0, 1, . . .)	fractional population of ions of species k in plasma
$p_{k,\,v}$	$(\partial p_k/\partial v)_\theta$
$p_{k,\,\theta}$	$(\partial p_k/\partial \theta)_v$
Q	Eq. (5)
Q_{ij}	mean interaction energy between an electron in shell i and one in shell j.
Q(x, y)	Eq. (A-18)
q	z'/Z

R	we determine u_{max} so that δ_p is almost certainly less than R; Eq. (D-9)
$R_{k\theta}$	a quantity occurring in the calculation of the temperature derivative of the fractional populations p_k; Eq. (A-53)
r	electron radial coordinate = distance from nucleus
$r = r_{ij}$	square of the radial matrix element for bound-bound transitions
$r = r_{ij} = r(k)$	1/k times the square of the radial matrix element for bound-free transitions. The free electron wave function is normalized to unit amplitude at large distances from the nucleus
S	specific entropy
S	Eq. (93)
S_c	Eq. (97)
s	sum of mean and mean square charges per ion
s_0	a cutoff parameter used in the calculation of the pressure lowering of ionization potentials
s_v	$(\partial s/\partial v)_\theta$
s_θ	$(\partial s/\partial \Theta)_v$
T	temperature
T_c	the transmission function associated with continuous absorption; Eq. (114)
$\overline{T}(u)$	mean transmission in the frequency interval $\delta(h\omega) = \Delta\Theta$ centered at u
$T_j(m, u)$	the statistical expectation value of $T_j^!$
$T_j^!(m, u)$	the frequency dependent fractional transmission of white light through an isothermal slab of mass depth m by the j^{th} line cluster; Eq. (105)

U_k	electronic partition function of ion of species k when energies are measured relative to the ground state energy of the ion; Eq. (63)
U_k^0	the contribution to the electronic partition function of an ion of species k by all sub-configurations listed for that species in Table 9; Eq. (71)
U_k^1	$= U_{k+1}^0$; Eq. (73)
U_k^E	the part of the electronic partition function of an ion of species k arising from electrons in E-type shells
U_k^H	the contribution of hydrogenic type ($\ell \geq 4$) states to the part U_k^E of the electronic partition function of the k^{th} ion; Eq. (A-11)
U_k^i (i = 1, . . .,5)	the contribution of $s_{\frac{1}{2}}$, $p_{\frac{1}{2}}$, $p_{\frac{3}{2}}$, d and f states to U_k^E
$U_{k,\beta}$	$(\partial U_k/\partial\beta)_v$
$U_{k,\beta\beta}$	$(\partial^2 U_k/\partial\beta^2)_v$
U_1	$I_d/\circledR$
$\Gamma(\frac{1}{2}, x)$	$= \pi^{-\frac{1}{2}} H(\frac{1}{2}, x)$; Table 26
u	$h\nu/k_BT = \hbar\omega/k_BT$
u_0	the most probable value of u_1
u_1	frequency of line center in u units
u_{0j}	mean transition frequency in u units in the j^{th} line cluster
V	volume of plasma
V = V(r)	potential energy of an electron in a central field
v	min(j, j'); Eq. (121)

W	specific enthalpy; Eq. (A-32)
$W(a, \tau_0)$	curve of growth; Eq. (C-3)
$W^*(a, \tau_0)$	a renormalized curve of growth; Eq. (C-6)
$W^*_L(\tau_0)$	is proportional to the Ladenburg-Reiche function; Eq. (C-8)
$W^*_0(\tau_0)$	is proportional to the curve of growth for a pure Doppler line shape
w'	half intensity half width of an absorption line
w'_e	the line half width at half intensity arising from electron collisions; Eq. (126)
x	displacement of frequency from cluster center in units of cluster width D
x	a quantity used in the calculation of F_p; Eqs. (A-37, A-38)
$x = r/\mu$	
Z	atomic number
Z_k	electronic partition function of ion of k^{th} species; Eq. (44); the zero of energy is that defined above
Z_0	first estimate of the normalization factor Z appearing in the calculation of populations; p. 147
z_β	charge of the β^{th} particle in plasma
$z' = k+1$	core charge
$\overline{z} = \overline{k}$	mean charge of a plasma ion
$\overline{z^2} = \overline{k^2}$	mean square charge of a plasma ion
$\overline{z^n}$	mean value of n^{th} power of charge of a plasma ion (defined on page 158)
$\overline{z}_v$	$(\partial\overline{z}/\partial v)_\theta$
$\overline{z}_\theta$	$(\partial\overline{z}/\partial\Theta)_v$
z^*	$\overline{z^2}/\overline{z}$; Eq. (46)

α	fine structure constant
α	scaling parameter in scaled Thomas-Fermi model
β	$\circledR^{-1}$
β	parameter in f(J)
$\beta(x)$	a function used in fitting the Voigt function; Eq. (C-15)
Γ	free electron degeneracy factor (Eq. A-1)
Δ	$\delta(\hbar\omega)/\circledR$
ΔE_k	lowering of ionization potential in an ion of the k^{th} species
$\Delta^2E(i^2 \rightarrow ij)$	the variance of the two-electron array in which the jumping electron is an equivalent one in the initial state
$\Delta^2E(ij \rightarrow j^2)$	the variance of the two-electron array in which the jumping electron is an equivalent one in the final state
$\Delta^2E(ik)$	variance of the two-electron subconfiguration having an electron in shell i and one in shell k.
$\Delta^2E(ik \rightarrow jk)$	the variance of a two-electron array in which the electron in shell i jumps to the shell j. The electron in shell k is not equivalent to the i or j shell electron
$\Delta^2E(\{N_i\})$	energy variance of subconfiguration with occupation numbers $\{N_i\}$; Eq. (21)
$\Delta^2E(N_i, N_j-1, \{N_k\} \rightarrow N_i-1, N_j, \{N_k\})$	the variance of the transition array $\{N_i, N_{j-1}, \{N_k\}\} \rightarrow \{N_{i-1}, N_j, \{N_k\}\}$
δ_p	Eq. (D-3)
$\epsilon_i = \epsilon(i)$	binding energy of electrons in single-electron state i
$\epsilon_k(\{N_i\}) = E_k(K)$	mean binding energy of an electron in k^{th} shell of an ion in subconfiguration K = $\{N_i\}$; Eq. (12)

Θ	$k_B T$; temperature in energy units
κ	a quantum number occurring in the Dirac theory; Eq. (6)
κ'	a factor which contains the explicit dependence of the strength of a transition array on the occupation numbers of the shells participating in the transition (Table 14)
κ_p	the overall Planck mean opacity; Eq. (D-1)
$\kappa_R(u)$	the local Rosseland mean opacity
$\kappa'_{bb}(u)$	monochromatic bound-bound absorption coefficient (cm^2/gm)
$\kappa'_{bf}(u)$	monochromatic bound-free absorption coefficient (cm^2/gm)
$\kappa_p(u)$	local Planck mean opacity (cm^2/gm)
$\kappa_c(u)$	continuous local Planck mean (cm^2/gm)
$\kappa_{ff}(u)$	free-free absorption coefficient (cm^2/gm)
$\langle\kappa'_{bb}(u)\rangle$	the statistical expectation value of κ'_{bb}
$\langle\kappa'_{bf}(u)\rangle$	the statistical expectation value of κ'_{bf}
$\kappa_{p,j}(u)$	the contribution of the j^{th} line cluster to the local Planck mean opacity (cm^2/gm)
$\kappa'_{bb,j}(u)$	the contribution of the j^{th} line cluster to the monochromatic absorption coefficient (cm^2/gm)
Λ_0	Eq. (42)
Λ_e	Eq. (43)
μ	$0.8853\ Z^{-1/3}$
$\mu_{as,k}(i)$	the asymptotic quantum defect (see Eq. (19))
μ_e	chemical potential of free electrons
$\mu_i = \mu(i)$	quantum defect associated with state i [Eq. (1)]
μ_k	chemical potential of k^{th} ionic species

$\nu = \omega/2\pi$	photon frequency
ν_{max}	upper limit of frequency range in opacity calculations
ρ	density
σ	average photoelectric cross section per initial state
σ, m	parameters in the state distribution function F(E)
σ_{ij}	Eq. (91)
$\sigma_{ij}^{2}(k)$	Eq. (96)
$\sigma_{ij}^{(Lin)}$	the cross section per state in the initial subconfiguration for a line of average strength and width for a transition array in which an ion of the k^{th} species in an initial subconfiguration absorbs a photon of frequency ω and makes a transition to a final subconfiguration; Eq. (89)
$\sigma_k(K)$	the value that the parameter σ in F(E) (Eq. (20)) takes for the subconfiguration K of an ion of species K
$\overline{\sigma} = \overline{\sigma}_{ij}$	average value of $\sigma_{ij}^{(Lin)}$ over an energy interval $\delta(\hbar\omega)$ much greater than w
τ	specific volume
$\overline{\tau}$	the optical depth at the cluster center divided by the number of lines in the cluster
τ_0	optical depth at center of a cluster; Eq. (C-4)
$\phi = \phi(x)$	Thomas-Fermi function; Eq. (10)
ϕ_k	Eq. (A-4)
$\phi_k(K)$	the contribution to the electronic partition function from all levels of the subconfiguration K in an ion of the k^{th} species; Eq. (72)
$\overline{\Psi}_\alpha(a_j)$	average electric potential produced at the position of the ion α by all other charged particles
Ω	$F-\Sigma\mu_k n_k-\mu_e n_e$; Eq. (60)

1. INTRODUCTION

Thermal radiation is the dominant mechanism for energy transfer in proposed gaseous-core nuclear rocket engines. Its calculation requires a knowledge of the thermodynamic and optical properties of the nuclear fuel. Here we consider these properties in a reactor using gaseous uranium as the fissionable fuel, and operating at temperatures of the order of 10^4 to 10^5 ^oK and pressures of the order of 10^2 to 10^3 atmospheres. The mean degree of ionization of the gas ranges from nearly zero at the lower temperatures to six or seven at the higher ones.

The calculation of the thermodynamic and optical properties of a heavy-element gas under the stated conditions is extremely difficult. At the lowest temperatures of interest to us, much of the internal energy of the plasma may reside in many low-lying levels of one or two of the most tightly bound configurations of electrons. The pertinent level schemes are extremely complicated and not known in very great detail. Optical properties require the calculation of transmission by line arrays whose complexity presents even more formidable problems than arise in the determination of level schemes.

Even if all the required information were available, it would not be practical to incorporate it into a computer program designed for the rapid calculation of physical properties. The number of energy levels and transitions in a complex atom like uranium is enormous. In the transition array $5f^3\ 6d\ 7s^2 \rightarrow 5f^2\ 6d^2\ 7s^2$, for example, there are thousands of spectral lines. The mere presentation of such detailed calculations would be a problem of considerable proportion. We avoid such a detailed approach not only because of its extreme difficulty but also because of the almost complete lack of required information.

In spite of the difficulties, there have been a number of studies of properties of uranium. Judd[1] has made the most systematic theoretical study of the energy-level structure in uranium. Judd's calculations of the deepest levels in the configuration $5f^3$ 6d $7s^2$ of UI are in good agreement with the results of spectroscopic measurements. The number of known levels is nevertheless only a very small fraction of the total. Recently, Gurvich and Yugman,[2] using the known energy levels, have calculated thermodynamic functions of gaseous uranium for temperatures below 20,000°K. They make rough estimates of the errors resulting from states whose energies are not known. Krascella has used a semi-empirical method[3] to calculate the spectral absorption coefficient and the Rosseland mean opacity of gaseous uranium. Since theirs is a semi-empirical method, it is difficult to assess its validity from the point of view of first principles. Moreover, assessment of their method from an empirical point of view is difficult in the absence of data on absorption coefficients over a broad range of temperature and densities.

In the present work, we approach the problem using methods that remain in substantial contact with first principles. Further, by supplementing X-ray levels with the recent results of extensive (but by no means exhaustive) self-consistent-field calculations of atomic energy levels performed at Los Alamos,[4] we are starting from a foundation that is considerably firmer than that which existed a few years ago.

For neutral uranium the binding energies associated with most of the spin-orbitals fully occupied in the ground state are known accurately from experimental X-ray data[5][6] and from calculations (see Table 1). For UI through UXII, which are all the ions that we need to consider for the present application, one-electron binding energies associated with spin-orbitals occupied in ground ionic states have been calculated[4][8] by means of relativistic Hartree-Fock-Slater (RHFS) equations with an exchange term having a magnitude two thirds of that originally introduced by Slater. Table 2 summarises some results of the calculation.

TABLE 1

ONE-ELECTRON BINDING ENERGIES IN NEUTRAL URANIUM
(In Rydbergs)

nl	j	Sandström (Ref. 5)	Bearden & Burr (Ref. 6)	Herman & Skillman (Ref. 7)	RHFS Eigenvalue (Ref. 4)	RHFS Binding Energy (Ref. 4)
1s	1/2	8514.7	8497.1	8486.3	8507.3	8580.2
2s	1/2	1602.6	1599.2	1564.2	1588.8	1617.7
2p	1/2	1542.2	1539.7	1503.4	1532.0	1559.8
2p	3/2	1264.2	1261.7	1299.2	1250.8	1274.9
3s	1/2	408.5	407.8	400.3	400.9	415.0
3p	1/2	381.4	380.9	373.9	375.2	388.7
3p	3/2	316.6	316.3	327.6	310.4	322.4
3d	3/2	273.9	274.0	287.9	269.6	280.4
3d	5/2	261.5	261.0	274.9	256.4	267.0
4s	1/2	105.5	105.9	103.9	102.0	109.4
4p	1/2	92.3	93.5	92.17	90.44	97.36
4p	3/2	76.6	76.8	80.19	73.53	79.78
4d	3/2	57.3	57.4	61.58	55.07	60.44
4d	5/2	54.1	54.2	58.52	51.96	57.17
4f	5/2	28.4	28.8	33.45	27.67	31.69
4f	7/2	27.9	28.0	32.56	26.86	30.82
5s	1/2	23.6	23.8	23.91	22.66	25.76
5p	1/2	18.6	19.1	19.32	18.15	20.91
5p	3/2	14.5	14.3	16.45	14.13	16.61
5d	3/2	7.2	7.72	9.536	7.556	9.352
5d	5/2		7.08	8.926	6.961	8.692
5f	5/2			1.350	0.2606	0.7899
5f	7/2					
6s	1/2		5.20	4.036	3.497	4.646
6p	1/2	2.2	3.11	2.673	2.198	3.077
6p	3/2		2.37	2.190	1.542	2.263
6d	3/2		0.28	0.549	0.2146	0.3328
6d	5/2			0.494		
7s	1/2			0.463	0.3517	0.5804

TABLE 2

RHFS BINDING ENERGIES (In Rydbergs)

	z'											
nl j	1	2	3	4	5	6	7	8	9	10	11	12
1s 1/2	8.5802+03	8.5808+03	8.5810+03	8.5819+03	8.5831+03	8.5843+03	8.5857+03	8.5869+03	8.5882+03	8.5895+03	8.5909+03	8.5924+03
2s 1/2	1.6177+03	1.6182+03	1.6184+03	1.6194+03	1.6206+03	1.6219+03	1.6233+03	1.6245+03	1.6257+03	1.6270+03	1.6284+03	1.6298+03
2p 1/2	1.5598+03	1.5604+03	1.5605+03	1.5615+03	1.5627+03	1.5640+03	1.5654+03	1.5666+03	1.5678+03	1.5691+03	1.5705+03	1.5720+03
2p 3/2	1.2749+03	1.2754+03	1.2756+03	1.2766+03	1.2777+03	1.2790+03	1.2804+03	1.2816+03	1.2829+03	1.2842+03	1.2855+03	1.2870+03
3s 1/2	4.1504+02	4.1556+02	4.1571+02	4.1670+02	4.1789+02	4.1922+02	4.2066+02	4.2185+02	4.2309+02	4.2437+02	4.2569+02	4.2715+02
3p 1/2	3.8871+02	3.8922+02	3.8938+02	3.9037+02	3.9155+02	3.9288+02	3.9433+02	3.9552+02	3.9675+02	3.9803+02	3.9936+02	4.0082+02
3p 3/2	3.2242+02	3.2294+02	3.2309+02	3.2409+02	3.2527+02	3.2660+02	3.2805+02	3.2924+02	3.3047+02	3.3175+02	3.3307+02	3.3453+02
3d 3/2	2.8044+02	2.8096+02	2.8111+02	2.8210+02	2.8329+02	2.8461+02	2.8606+02	2.8725+02	2.8849+02	2.8977+02	2.9109+02	2.9255+02
3d 5/2	2.6698+02	2.6749+02	2.6764+02	2.6864+02	2.6982+02	2.7115+02	2.7260+02	2.7379+02	2.7502+02	2.7630+02	2.7763+02	2.7909+02
4s 1/2	1.0940+02	1.0992+02	1.1007+02	1.1106+02	1.1224+02	1.1356+02	1.1499+02	1.1617+02	1.1739+02	1.1866+02	1.1997+02	1.2141+02
4p 1/2	9.7361+01	9.7874+01	9.8029+01	9.9022+01	1.0020+02	1.0152+02	1.0295+02	1.0413+02	1.0535+02	1.0662+02	1.0793+02	1.0937+02
4p 3/2	7.9767+01	8.0280+01	8.0435+01	8.1428+01	8.2604+01	8.3918+01	8.5349+01	8.6525+01	8.7747+01	8.9011+01	9.0317+01	9.1757+01
4d 3/2	6.0440+01	6.0953+01	6.1108+01	6.2100+01	6.3277+01	6.4592+01	6.6023+01	6.7200+01	6.8421+01	6.9685+01	7.0992+01	7.2431+01
4d 5/2	5.7169+01	5.7682+01	5.7837+01	5.8830+01	6.0006+01	6.1320+01	6.2750+01	6.3927+01	6.5147+01	6.6410+01	6.7716+01	6.9154+01
4f 5/2	3.1691+01	3.2203+01	3.2356+01	3.3351+01	3.4529+01	3.5846+01	3.7280+01	3.8457+01	3.9677+01	4.0940+01	4.2246+01	4.3684+01
4f 7/2	3.0821+01	3.1333+01	3.1486+01	3.2481+01	3.3659+01	3.4975+01	3.6409+01	3.7585+01	3.8805+01	4.0068+01	4.1373+01	4.2811+01
5s 1/2	2.5761+01	2.6272+01	2.6430+01	2.7416+01	2.8576+01	2.9863+01	3.1254+01	3.2408+01	3.3601+01	3.4834+01	3.6105+01	3.7501+01
5p 1/2	2.0911+01	2.1422+01	2.1582+01	2.2564+01	2.3720+01	2.5001+01	2.6384+01	2.7535+01	2.8726+01	2.9956+01	3.1224+01	3.2615+01
5p 3/2	1.6606+01	1.7118+01	1.7285+01	1.8259+01	1.9402+01	2.0665+01	2.2026+01	2.3170+01	2.4353+01	2.5575+01	2.6833+01	2.8211+01
5d 3/2	9.3516+00	9.8645+00	1.0040+01	1.1003+01	1.2127+01	1.3364+01	1.4694+01	1.5827+01	1.6999+01	1.8206+01	1.9450+01	2.0806+01
5d 5/2	8.6916+00	9.2048+00	9.3832+00	1.0342+01	1.1461+01	1.2691+01	1.4012+01	1.5142+01	1.6310+01	1.7513+01	1.8752+01	2.0102+01
5f 5/2	7.8987-01	1.3007+00	1.4800+00	2.4212+00	3.4768+00	4.6207+00						
6s 1/2	4.6456+00	5.1578+00	5.4091+00	6.2829+00	7.2739+00	8.3429+00	9.4743+00	1.0506+01	1.1567+01	1.2658+01	1.3789+01	1.4988+01
6p 1/2	3.0770+00	3.5824+00	3.8609+00	4.7094+00	5.6655+00	6.6950+00	7.7826+00	8.7815+00	9.8080+00	1.0865+01	1.1961+01	1.3118+01
6p 3/2	2.2630+00	2.7590+00	3.0741+00	3.8921+00	4.8054+00	5.7832+00	6.8151+00	7.7740+00	8.7594+00	9.7755+00		
6d 3/2	3.3280-01											
7s 1/2	5.8040-01	1.0108+00										

NOTE: The numbers listed are $(-1) \times \epsilon_i$.

Our approach is based on the use of a simple central field, the scaled Thomas-Fermi (STF) potential,[9] which in nonrelativistic examples appears to be about as accurate as the Hartree-Fock-Slater potential when both are compared with the full Hartree-Fock method. The STF potential contains an adjustable scaling parameter α, which in Ref. 9 was calibrated to experimental energies In the present work, we use the RHFS calculation and neutral-atom X-ray energies to calibrate the STF potential. From this potential we can then generate the numerous spin-orbitals that we require in the calculation of opacities.

Initially, we consider only the one-electron aspects of the electrons bound in a given ion. (Later, we shall consider the effect of the multiplet and fine structure produced by departures from spherical symmetry.) Each spin-orbital is labeled by one-electron quantum numbers n, ℓ, j. Here, n and ℓ are the principal and orbital quantum numbers, respectively, and $j = \ell (\pm) 1/2$ is the one-electron total angular momentum quantum number.

For outer-atom electrons with $\ell \geq 2$, the binding energy is not very sensitive to j. Furthermore, numerical calculations that we have done show that the oscillator strength corresponding to a one-electron transition of an electron with $\ell \geq 2$ in either the initial or final state is not very sensitive to the value of j associated with this ℓ for strong transitions, e.g., for same-shell (n=n') transitions. For these reasons, very little effect on thermodynamic or optical properties results from spin-orbit splitting of one-electron levels with $\ell \geq 2$. Thus, the one-electron states from which we build up an ionic state are $ns_{\frac{1}{2}}$, $np_{\frac{1}{2}}$, $np_{\frac{3}{2}}$, nd, nf, etc., states. An electron having quantum numbers $n\ell$ ($n\ell j$) is said to be in the $n\ell$ ($n\ell j$) shell. The specification of the number of electrons in each occupied shell in an ion will define a subconfiguration. By a transition array we shall mean the totality of all allowed electric dipole transitions between a pair of subconfigurations.

We take the point of view that wave functions generated from the one-electron Dirac equation with the STF potential form a complete set in terms

of which we can describe the bound-state properties of any of the many-electron ions in our system. The relevant properties of a one-electron state $|i)$ are (1) the radial wave function P_i, (2) the one-electron eigenvalues ϵ_i, and (3) the associated quantum defects μ_i defined by

$$\epsilon_i = -\frac{(k+1)^2}{(n-\mu_i)^2} , \tag{1}$$

where k is the net ionic charge. From the radial wave functions we can calculate the mean interaction energy between a pair of electrons, the strength of a transition array, and certain average properties of a collection of levels or lines associated with a subconfiguration or transition array.

We have already mentioned the enormous number of levels and lines that occur when one is dealing with complex atoms. For these atoms the statistical properties of level and line distribution are of considerable interest. The properties of importance in the present context are the level- and line-distribution functions, and in particular the first and second moments of these distributions. From the statistical properties we can estimate the effect of fine structure on the electronic partition function and the effect of a cluster of lines on the transmission of radiation through a slab of arbitrary thickness. In general, these effects are important in our problem, the former for the internal energy, the latter for the opacity of the uranium plasma. A more detailed discussion of statistical aspects of atomic spectra and their application to our problem is given in Sec. 2.3 and Sec. 5.

2. ATOMIC STATES

2.1. ONE-ELECTRON WAVE FUNCTIONS

The states that form the quantitative basis for future calculations are generated as solutions of a one-electron Dirac equation with a scaled STF potential. The scaling parameter α is chosen by calibration against known X-ray levels and the results of self-consistent-field calculations.

Before proceeding further, we should emphasize the importance of a relativistic description of our system. This is especially true since at the low temperatures of interest to us only electrons with binding energies $\epsilon_i << mc^2$ undergo collisional and radiative transitions at a significant rate. Nevertheless, even these electrons may have a significant probability for being found near the nucleus and consequently may be bound much more tightly than would be the case in the absence of relativistic effects. This direct relativistic effect in uranium is relatively large (~25%), even for large principal quantum numbers n, especially if the classical orbit is highly noncircular (s- and p-electrons). Furthermore, the tighter binding associated with direct relativistic effects leads to a wave function that is more localized around the nucleus. In turn, the increased localization results in an increased shielding of the effective charge seen by other electrons. In contrast to the direct effect, this indirect shielding effect tends to reduce the binding energy of outer electrons. The indirect effect, however, would not be exhibited in the framework of a one-electron theory, but only in a many-body calculation.

Although relativistic effects are important, the dominant contributions to Slater integrals and transition integrals come from spatial regions where the electron is locally nonrelativistic and where the small component of the

full Dirac wave function is negligible. In the following, we therefore eliminate the small component from the Dirac equation and use only the large component in the calculation of the normalization integrals, Slater integrals, and transition integrals.

We let f(r) and g(r) represent the radial dependence of the large and small components, respectively, of the Dirac wave function. The normalization is such that

$$\int_0^\infty r^2[f^2(r) + g^2(r)]\, dr = 1 \quad . \tag{2}$$

If we eliminate g(r) from the pair of first-order radial Dirac equations and introduce

$$P(r) = \left(\frac{E - V + mc^2}{mc^2}\right)^{\frac{1}{2}} rf(r) \quad , \tag{3}$$

we find[10]

$$P'' + \left\{\left[\frac{(E - V)^2 - m^2c^4}{(\hbar c)^2} + \frac{\kappa}{r}\frac{V'}{Q} - \frac{\kappa(\kappa + 1)}{r^2}\right] - \frac{1}{2}\frac{V''}{Q} - \frac{3}{4}\left(\frac{V'}{Q}\right)^2\right\} P = 0 \quad , \tag{4}$$

where

$$Q = E - V + mc^2 \quad , \tag{5}$$

the prime implies differentiation with respect to r, and

$$\begin{aligned} \kappa &= -(\ell + 1) \qquad \text{if } j = \ell + \tfrac{1}{2} \quad , \\ &= \ell \qquad\quad \text{if } j = \ell - \tfrac{1}{2} \quad . \end{aligned} \tag{6}$$

This equation, which we solve numerically on a high-speed computer, is the basis for the relativistic generalization of the BERN code used by Stewart and Rotenberg[9] in their calculation of nonrelativistic wave function.

For outer electrons, it is accurate to replace the normalization

condition (2) by

$$\int_0^\infty [P(r)]^2 \, dr = 1 \quad . \tag{7}$$

We can now calculate Slater integrals and electric dipole matrix elements by precisely the same formulas that would apply if P were obtained as a solution of the nonrelativistic Schrödinger equation. That this is an accurate procedure is assured by the smallness of g(r) in the outer regions of the atom, where the principal contributions to the integrals arise.

The potential energy is

$$V(r) = -\frac{Ze^2}{r}\psi(r/\alpha\mu) \quad , \tag{8}$$

where

$$\begin{aligned} \psi(x) &= \phi(x) + qx/x_0 \qquad && x \leq x_0 \quad , \\ &= q && x \geq x_0 \quad . \end{aligned} \tag{9}$$

The boundary of the ion is at x_0, and ϕ, the TF function, satisfies

$$\frac{d^2\phi}{dx^2} = \phi^{\frac{3}{2}} x^{-\frac{1}{2}} \tag{10}$$

$$\phi(0) = 1$$

$$\phi(x_0) = 0$$

$$q = -x_0 \left.\frac{d\phi}{dx}\right|_{x_0}$$

$$x = r/\mu$$

$$\mu = 0.8853\, Z^{-\frac{1}{3}}$$

$$q = z'/Z$$

z' = core charge = $k + 1$

Z = atomic number.

The scale factor α was introduced into the TF potential by Stewart and Rotenberg and used as the basis of a semi-empirical method for computing atomic and ionic wave functions.[9] In their paper, α played the role of an eigenvalue to be determined by equating the energy eigenvalue in the Schrödinger equation to the experimental one-electron binding energy. In the present work, we calibrate α against neutral-atom X-ray levels and the results of self-consistent-field calculations for both neutral and ionic species. Stewart and Rotenberg find that oscillator strengths obtained by their method agree with the results of alternative methods of calculation. Further, their method has a wide range of applicability and their calculations are much shorter than self-consistent-field calculations.

In Fig. 1 we have plotted the computed eigenvalues of several spin-orbitals in UI-UXII as functions of α. The upper member of a pair of connected curves corresponds to $j = \ell - \frac{1}{2}$; the lower one to $j = \ell + \frac{1}{2}$. From these graphs we can determine values of α that lead to binding energies closely reproducing the self-consistent-field results calculated at Los Alamos and shown in Table 2. Apparently, the values of α determined in this way are nearly independent of ℓ, j, and z but exhibit a relatively strong dependence on n. Even the 5f electron in neutral uranium, whose STF energy eigenvalue is extremely sensitive to α adheres to this rule. Table 3 shows the values of α finally selected for all spin-orbitals with principal quantum number $n = 5$ through $n = 10$. We disregard electrons with $n < 5$ since they do not have a significant probability of excitation in the range of temperatures and photon energies of interest here. We have constructed Table 3 ignoring, for the most part, any dependence on ℓ and j but accounting for the small variation with z'. The values of α for $n = 5$, 6, and 7 were determined on the basis of the RHFS binding energies; for $n = 7$, the α's for $z' > 2$ follow from the assumption that α is independent of z. For $n \geq 8$, we have no quantitative basis for determining α, and the value $\alpha = 1.10$ is merely

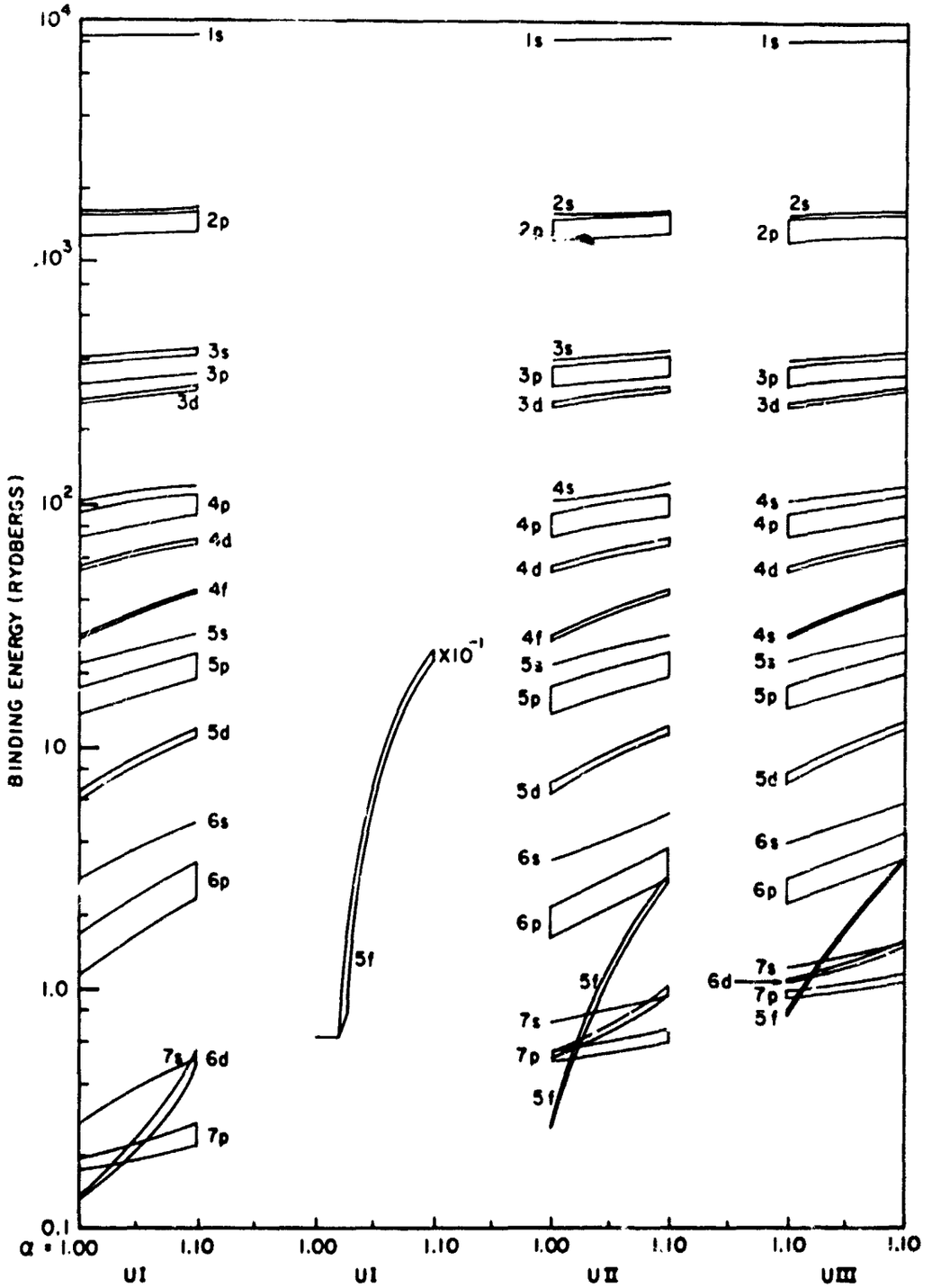


Fig. 1. Binding energy vs STF scaling parameter (sheet 1 of 4)

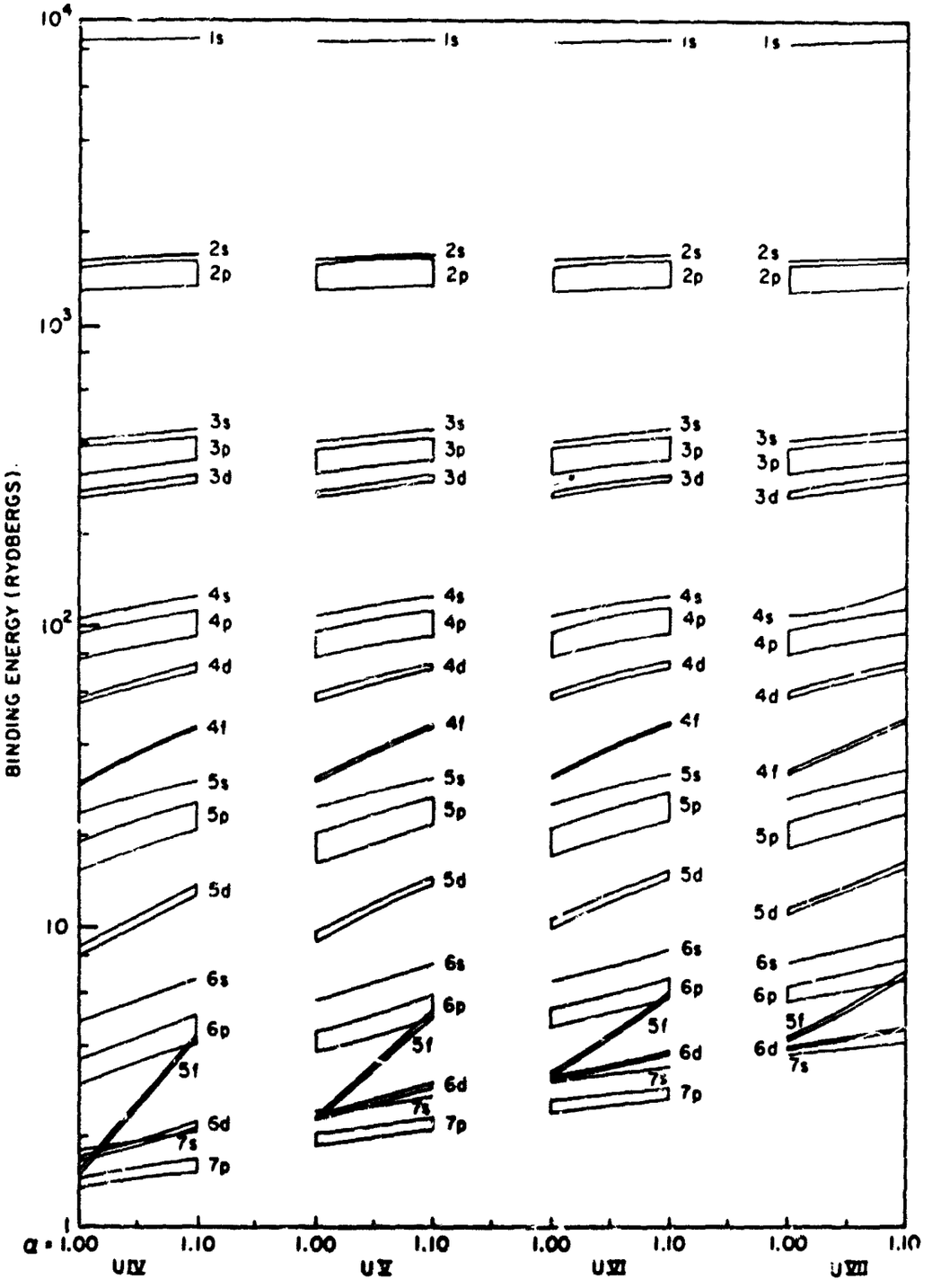


Fig. 1. Binding energy vs STF scaling parameter (sheet 2 of 4)

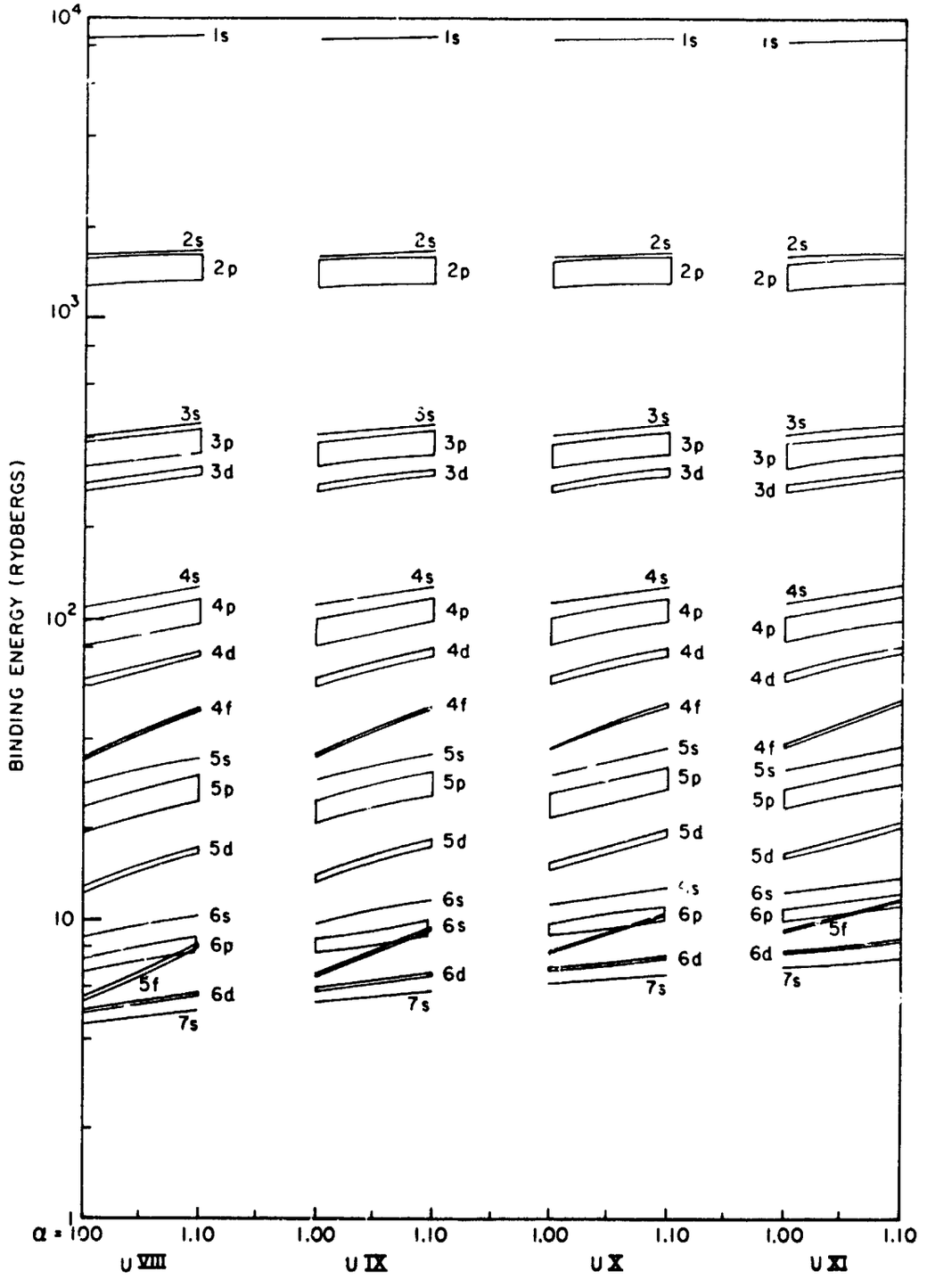


Fig. 1. Binding energy vs STF scaling parameter (sheet 3 of 4)

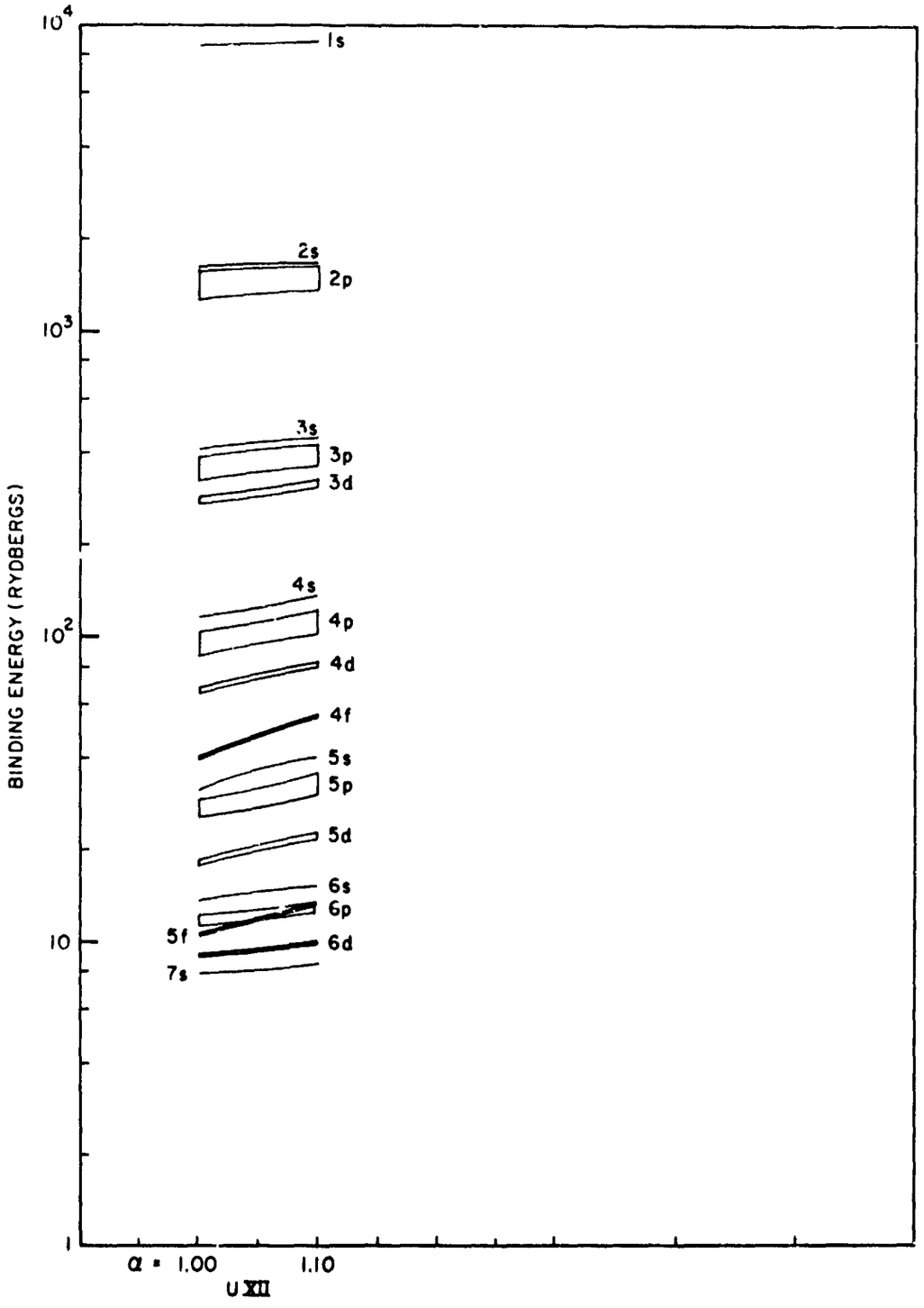


Fig. 1. Binding energy vs STF scaling parameter (sheet 4 of 4)

TABLE 3

STF SCALING PARAMETER

	z'											
n	1	2	3	4	5	6	7	8	9	10	11	12
5	1.053	1.06	1.05	1.05	1.05	1.055	1.068	1.062	1.068	1.06	1.057	1.055
6	1.091[a]	1.09	1.09[b]	1.08	1.09	1.095	1.10	1.10	1.10	1.08	1.08	1.08
7	1.15	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
8	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
9	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10

[a] For 6d electrons, α = 1.08.

[b] For 6p electrons, α = 1.085.

a guess on the part of the authors. Self-consistent-field calculations for excited ions including orbitals with $n \geq 8$ would provide a systematic basis for choosing α.

In Table 4, we list the eigenvalues obtained from Eq. (4) using the α's given in Table 3. These eigenvalues should be compared with the RHFS binding energies listed in Table 2. The quantum defects in Table 5 follow from the eigenvalues of Table 4 through the relation (1). The information contained in both of these tables is used extensively in the detailed energy-level and oscillator-strength calculations that we describe in subsequent parts of this report.

2.2. ATOMIC ENERGY LEVELS

To form a suitable working basis for the calculation of energy levels and electronic binding energies, we consider the kinds of states that are likely to occur in an ion or atom in a thermal equilibrium plasma. In general, in an ionic species that is relatively abundant in a high-Z plasma we will consider three classes of bound electrons (shells):

(1) I-electrons (shells) that are tightly bound in an inner core consisting entirely of closed shells. At thermal equilibrium the probability that I-electrons in an ion near the dominant species are excited into other one-electron states is negligibly small.

(2) E-electrons (shells). These electrons have excitation energies sufficiently large that the probability of finding more than one E-electron in an ion near the dominant species is negligibly small.

(3) M-electrons (shells). These electrons are in shells that may have any occupation consistent with the Pauli exclusion principle and the full occupation of the I-shells.

TABLE 4

STF EIGENVALUES[a] (In Rydbergs)

nl j	z'											
	1	2	3	4	5	6	7	8	9	10	11	12
5s 1/2	2.5516+01	2.6493+01	2.6421+01	2.7238+01	2.8120+01	2.9421+01	3.1433+01	3.2160+01	3.3809+01	3.4676+01	3.588e+01	3.7282+01
6	4.6361+00	5.0987+00	5.7154+00	6.2434+00	7.2734+00	8.2807+00	9.3621+00	1.0419+01	1.1544+01	1.2387+01	1.3642+01	1.4844+01
7	6.7551-01	1.0713+00	1.5996+00	2.1967+00	2.8538+00	3.5614+00	4.3131+00	5.1058+00	5.9399+00	6.8090+00	7.7108+00	8.6502+00
8	1.5437-01	4.0856-01	7.2583-01	1.0950+00	1.5093+00	1.9650+00	2.4577+00	2.9840+00	3.5467+00	4.1408+00	4.7648+00	5.4201+00
9	7.9109-02	2.3252-01	4.3711-01	6.8375-01	9.6730-01	1.2846+00	1.6329+00	2.0104+00	2.4170+00	2.8497+00	3.3055+00	3.7800+00
10	4.8017-02	1.5048-01	2.9267-01	4.6834-01	6.7382-01	9.0675-01	1.1651+00	1.4476+00	1.7539+00	2.0821+00	2.4310+00	2.8017+00
5p 1/2	2.0866+01	2.1873+01	2.1821+01	2.2590+01	2.3468+01	2.4806+01	2.6759+01	2.7525+01	2.9[illegible]3+01	3.0006+01	3.1264+01	3.2674+01
6	3.1376+00	3.6003+00	4.1245+00	4.7666+00	5.7530+00	6.7388+00	7.7931+00	8.8325+00	9.9365+00	1.0797+01	1.2023+01	1.3301+01
7	3.6154-01	7.4886-01	1.2436+00	1.8045+00	2.4215+00	3.0863+00	3.7966+00	4.5475+00	5.3374+00	6.1649+00	7.0292+00	7.9284+00
8	1.1139-01	3.2315-01	6.1173-01	9.4883-01	1.3321+00	1.7563+00	2.2203+00	2.7190+00	3.2517+00	3.8175+00	4.4148+00	5.0427+00
9	6.1968-02	1.9668-01	3.8209-01	6.0949-01	8.7382-01	1.1719+00	1.5010+00	1.8596+00	2.2461+00	2.6598+00	3.0992+00	3.5642+00
10	3.9600-02	1.3139-01	2.6189-01	4.2543-01	6.1848-01	8.3874-01	1.0844+00	1.3540+00	1.6467+00	1.9618+00	2.2985+00	2.6561+00
5p 3/2	1.6239+01	1.7154+01	1.7205+01	1.7988+01	1.8864+01	2.0141+01	2.1952+01	2.2773+01	2.4355+01	2.5264+01	2.6504+01	2.7931+01
6	2.2212+00	2.6873+00	3.2290+00	3.8795+00	4.8132+00	5.7550+00	6.7686+00	7.7780+00	8.8404+00	9.7298+00	1.0907+01	1.2132+01
7	2.7713-01	6.4795-01	1.1126+00	1.6384+00	2.2173+00	2.8421+00	3.5106+00	4.2185+00	4.9647+00	5.7476+00	6.5668+00	7.4202+00
8	1.0056-01	3.0274-01	5.6925-01	8.8733-01	1.2501+00	1.6532+00	2.0934+00	2.5683+00	3.0763+00	3.6163+00	4.1872+00	4.7870+00
9	5.7551-02	1.8494-01	3.6110-01	5.7775-01	8.3013-01	1.1152+00	1.4305+00	1.7743+00	2.1455+00	2.5429+00	2.9655+00	3.4129+00
10	3.7350-02	1.2496-01	2.4994-01	4.0685-01	5.9238-01	8.0434-01	1.0410+00	1.3010+00	1.5835+00	1.8876+00	2.2130+00	2.5588+00
5d 3/2	9.2332+00	1.0115+01	1.0230+01	1.1006+01	1.1891+01	1.3124+01	1.4845+01	1.5691+01	1.7227+01	1.8173+01	1.9431+01	2.0833+01
6	3.9992-01	9.3402-01	1.5168+00	2.1191+00	2.9395+00	3.7970+00	4.7186+00	5.6609+00	6.6557+00	7.5288+00	8.6277+00	9.7528+00
7	1.1035-01	3.7686-01	7.3515-01	1.1610+00	1.6438+00	2.1779+00	2.7577+00	3.3827+00	4.0489+00	4.7548+00	5.4990+00	6.2802+00
8	5.9168-02	2.0723-01	4.1801-01	6.8062-01	9.8862-01	1.3381+00	1.7260+00	2.1495+00	2.6070+00	3.0967+00	3.6134+00	4.1706+00
9	3.8162-02	1.3684-01	2.8140-01	4.6521-01	6.8448-01	9.3591-01	1.2180+00	1.5286+00	1.8665+00	2.2300+00	2.6208+00	3.0394+00
10	2.6671-02	9.7223-02	2.0267-01	3.3874-01	5.0267-01	6.9236-01	9.0674-01	1.1442+00	1.4039+00	1.6852+00	1.9876+00	2.3103+00
5f 5/2	7.9681-01	1.5130+00	1.8503+00	2.6072+00	3.4678+00	4.5611+00	5.9855+00	6.[illegible]237+00	8.2959+00	9.3349+00	1.[illegible]593+01	1.[illegible]363+01
6	6.2636-02	2.5317-01	5.7208-01	9.9527-01	1.5294+00	2.1454+00	2.8386+00	3.[illegible]825+00	4.3847+00	5.1393+00	6.[illegible]367+00	6.[illegible]633+00
7	4.0176-02	1.6537-01	3.8187-01	6.7440-01	1.0289+00	1.4373+00	1.8961+00	2.4005+00	2.9493+00	3.5403+00	4.[illegible]1734+00	4.[illegible]8423-01
8	2.7863-02	1.1319-01	2.5628-01	4.4978-01	6.8715-01	9.6471-01	1.2796+00	1.6305+00	2.0154+00	2.4333+00	2.8832+00	3.3634+00
9	2.0467-02	8.3090-02	1.8790-01	3.2995-01	5.0524-01	7.1146-01	9.4693-01	1.2103+00	1.5007+00	1.8172+00	2.1592+00	2.5261+00
10	1.5669-02	6.3532-02	1.4358-01	2.5230-01	3.8719-01	5.4649-01	7.2924-01	9.3443-01	1.1614+00	1.4095+00	1.6[illegible]84+00	1.9[illegible]74+00
5g 1/2	4.0010-02	1.6005-01	3.6042-01	6.4193-01	1.0060+00	1.4554+00	1.9969+00	2.6254+00	3.3580+00	4.1720+00	5.[illegible]859+00	6.[illegible]041+00
6	2.7783-02	1.1120-01	2.5054-01	4.4688-01	7.0297-01	1.0232+00	1.4146+00	1.8813+00	2.4258+00	2.9955+00	3.[illegible]704+00	4.4110+00
7	2.0413-02	8.1711-02	1.8433-01	3.2980-01	5.2167-01	7.6731-01	1.0765+00	1.4513+00	1.8813+00	2.3566+00	2.8731+00	3.4303+00
8	1.5628-02	6.2538-02	1.4102-01	2.5185-01	3.9677-01	5.7876-01	8.0149-01	1.0676+00	1.3753+00	1.7206+00	2.1002+00	2.5113+00
9	1.2347-02	4.9421-02	1.1143-01	1.9896-01	3.1341-01	4.5712-01	6.3288-01	8.4202-01	1.0827+00	1.3513+00	1.647[illegible]+00	1.9683+00
10	1.0002-02	4.0030-02	9.0247-02	1.6113-01	2.5372-01	3.6991-01	5.1178-01	6.8003-01	8.7296-01	1.0883+00	1.3247+00	1.5815+00

[a] STF eigenvalues (Rydbergs) obtained using the scaling parameters in Table 3.

NOTE: The numbers listed here are $(-1) \times \epsilon_i$.

TABLE 5

STF QUANTUM DEFECTS[a]

nl j	Z											
	1	2	3	4	5	6	7	8	9	10	11	12
5s 1/2	4.8020+00	4.6114+00	4.4164+00	4.2336+00	4.0571+00	3.8938+00	3.7515+00	3.5893+00	3.4922+00	3.3018+00	3.1637+00	3.0347+00
6	5.5356+00	5.1143+00	4.7451+00	4.3992+00	4.1460+00	3.9149+00	3.7122+00	3.5216+00	3.3511+00	3.1587+00	3.0218+00	2.8958+00
7	5.7833+00	5.0677+00	4.6280+00	4.3012+00	4.0402+00	3.8206+00	3.6294+00	3.4596+00	3.3072+00	3.1677+00	3.0387+00	2.9199+00
8	5.4548+00	4.8710+00	4.4797+00	4.1775+00	3.9302+00	3.7197+00	3.5349+00	3.3688+00	3.2211+00	3.0858+00	2.9607+00	2.8456+00
9	5.4446+00	4.8524+00	4.4624+00	4.1626+00	3.9162+00	3.7063+00	3.5221+00	3.3578+00	3.2110+00	3.0762+00	2.9498+00	2.8352+00
10	5.4364+00	4.8442+00	4.4546+00	4.1550+00	3.9089+00	3.6990+00	3.5150+00	3.3510+00	3.2043+00	3.0697+00	2.9450+00	2.8308+00
5p 1/2	4.7811+00	4.5724+00	4.3578+00	4.1584+00	3.9679+00	3.7953+00	3.6468+00	3.4752+00	3.3334+00	3.1745+00	3.0327+00	2.9007+00
6	5.4355+00	4.9459+00	4.5228+00	4.1679+00	3.9154+00	3.7687+00	3.4925+00	3.3082+00	3.1449+00	2.9567+00	2.8276+00	2.7096+00
7	5.3369+00	4.6888+00	4.3098+00	4.0223+00	3.7868+00	3.5847+00	3.4075+00	3.2485+00	3.1044+00	2.9725+00	2.8510+00	2.7382+00
8	5.0030+00	4.5087+00	4.1643+00	3.8936+00	3.6679+00	3.4726+00	3.3022+00	3.1484+00	3.0090+00	2.8819+00	2.7647+00	2.6562+00
9	4.9320+00	4.4903+00	4.1467+00	3.8764+00	3.6512+00	3.4574+00	3.2865+00	3.1335+00	2.9948+00	2.8684+00	2.7516+00	2.6438+00
10	4.9748+00	4.4824+00	4.1378+00	3.8674+00	3.6422+00	3.4485+00	3.2779+00	3.1249+00	2.9865+00	2.8604+00	2.7444+00	2.6370+00
5p 3/2	4.7518+00	4.5171+00	4.2767+00	4.0569+00	3.8488+00	3.6631+00	3.5060+00	3.3236+00	3.1763+00	3.0105+00	2.8635+00	2.7294+00
6	5.3290+00	4.7800+00	4.3305+00	3.9692+00	3.7210+00	3.4389+00	3.3094+00	3.1315+00	2.9741+00	2.7941+00	2.6602+00	2.5548+00
7	5.1004+00	4.5154+00	4.1559+00	3.8750+00	3.6422+00	3.4410+00	3.2640+00	3.1050+00	2.9608+00	2.8289+00	2.7074+00	2.5947+00
8	4.8465+00	4.3651+00	4.0238+00	3.7536+00	3.5280+00	3.3336+00	3.1620+00	3.0081+00	2.8687+00	2.7414+00	2.6244+00	2.5158+00
9	4.8316+00	4.3494+00	4.0076+00	3.7375+00	3.5122+00	3.3183+00	3.1474+00	2.9941+00	2.8556+00	2.7290+00	2.6124+00	2.5044+00
10	4.8256+00	4.3423+00	3.9992+00	3.7289+00	3.5031+00	3.3099+00	3.1391+00	2.9862+00	2.8478+00	2.7215+00	2.6056+00	2.4982+00
5d 3/2	4.6709+00	4.3711+00	4.0621+00	3.7943+00	3.5500+00	3.3438+00	3.1832+00	2.9804+00	2.8316+00	2.6942+00	2.5646+00	2.4420+00
6	4.4187+00	3.9306+00	3.5641+00	3.2522+00	3.0837+00	2.9209+00	2.7775+00	2.6376+00	2.5114+00	2.3555+00	2.2529+00	2.1575+00
7	3.9897+00	3.742+00	3.5011+00	3.2877+00	3.1002+00	2.9343+00	2.7847+00	2.6503+00	2.5273+00	2.4140+00	2.3092+00	2.2116+00
8	3.8889+00	3.6066+00	3.3599+00	3.1515+00	2.9713+00	2.8132+00	2.6718+00	2.5434+00	2.4260+00	2.3174+00	2.2173+00	2.1240+00
9	3.8810+00	3.5934+00	3.3447+00	3.1354+00	2.9565+00	2.7980+00	2.6573+00	2.5293+00	2.4125+00	2.3048+00	2.2052+00	2.1126+00
10	3.8767+00	3.5858+00	3.3361+00	3.1273+00	2.9477+00	2.7892+00	2.6488+00	2.5210+00	2.4042+00	2.2968+00	2.1978+00	2.1051+00
5f 5/2	3.8797+00	3.3740+00	2.7945+00	2.5227+00	2.3150+00	2.1906+00	2.1388+00	1.9597+00	1.8753+00	1.7270+00	1.6203+00	1.5290+00
6	2.0043+00	2.0251+00	2.0336+00	1.9905+00	1.9570+00	1.9037+00	1.8452+00	1.7733+00	1.7019+00	1.6889+00	1.5229+00	1.4590+00
7	2.0109+00	2.0819+00	2.1453+00	2.1292+00	2.0708+00	1.9954+00	1.9165+00	1.8366+00	1.7534+00	1.6853+00	1.6145+00	1.5470+00
8	2.0092+00	2.0553+00	2.0740+00	2.0357+00	1.9682+00	1.8912+00	1.8118+00	1.7350+00	1.6605+00	1.5893+00	1.5217+00	1.4567+00
9	2.0101+00	2.0616+00	2.0791+00	2.0364+00	1.9657+00	1.8866+00	1.8065+00	1.7283+00	1.6532+00	1.5818+00	1.5141+00	1.4490+00
10	2.0112+00	2.0653+00	2.0827+00	2.0366+00	1.9646+00	1.8837+00	1.8029+00	1.7241+00	1.6487+00	1.5770+00	1.5093+00	1.4451+00
5g 7/2	6.2311-04	7.4989-04	2.8808-03	7.5186-03	1.4998-02	2.6586-02	4.6356-02	6.2630-02	8.8609-02	1.0416-01	1.2217-01	1.3893-01
6	6.1327-04	2.3766-03	6.4105-03	1.6349-02	3.6474-02	6.8379-02	1.1457-01	1.6749-01	2.2146-01	2.2218-01	2.6837-01	2.8636-01
7	8.2743-04	3.3398-03	1.2534-02	3.4739-02	7.7367-02	1.5039-01	2.5342-01	3.5939-01	4.3826-01	4.8588-01	5.1038-01	5.2093-01
8	7.4470-04	2.4464-03	1.1269-02	2.9510-02	6.2182-02	1.1317-01	1.8107-01	2.5741-01	3.2549-01	3.7634-01	4.0968-01	4.2849-01
9	6.5565-04	3.5144-03	1.2830-02	3.2495-02	6.8784-02	1.2565-01	2.0092-01	2.8177-01	3.5059-01	3.9934-01	4.2981-01	4.4667-01
10	1.1737-03	3.6983-03	1.3695-02	3.5019-02	7.3614-02	1.3487-01	2.1509-01	2.9876-01	3.6737-01	4.1426-01	4.4267-01	4.5776-01

[a] STF Quantum Defects obtained from Table 4 and Eq. (1).

Thus, in an ion having N bound electrons, we consider as important for the statistical mechanics subconfigurations having

(a) an invariable number N_I of I-electrons,

(b) no more than one E-electron, and

(c) $N_M = N - N_I$ or $N_M = N - N_I - 1$ electrons of type M.

In Table 6 we give the classification adopted for the shells in each of the first twelve ionic species of uranium.

TABLE 6

CLASSIFICATION OF SPIN-ORBITALS

	z'											
nl j	1	2	3	4	5	6	7	8	9	10	11	12
6s 1/2	I	I	I	I	I	I	I	I	I	I	I	I
6p 1/2	I	I	I	I	I	M	M	M	M	M	M	M
6p 3/2	I	I	I	I	M	M	M	M	M	M	M	M
6d	M	M	M	M	M	E	E	E	E	E	E	E
5f	M	M	M	M	M	M	M	M	M	M	M	M
7s 1/2	M	M	M	M	E	E	E	E	E	E	E	E

NOTE: Electrons in K, L, M, N, or O shells are I-electrons.
Electron in shells not listed here are E-electrons.

We are now in a position to describe the method for calculating average energies of subconfigurations and the binding energies of electrons contained in them. We make the approximation that the one-electron wave function corresponding to a given spin-orbital is independent of the distribution of remaining electrons over one-electron states. (In general, this is a quite strong assumption; however, in view of the complexity of the problem we are trying to solve and the many sources of uncertainty inherent in it, there is hardly any basis for attempting to be more precise.) With this assumption

the average energy of the subconfiguration K with N_1 electrons in shell 1, N_2 in shell 2, etc., is[11]

$$E(K) = E(\{N_i\}) = \sum_i N_i f_i + \sum_i \frac{N_i(N_i-1)}{2} Q_{ii} + \frac{1}{2}\sum_{i\neq j} N_i N_j Q_{ij} \quad , \qquad (11)$$

and the mean binding energy of an electron in the k^{th} shell is

$$E_k(K) = \epsilon_k(\{N_i\}) = f_k + (N_k - 1)\, Q_{kk} + \sum_{j\neq k} N_j Q_{kj} \quad . \qquad (12)$$

Here we consider f_k to be the average value of the sum of the kinetic energy of an electron in shell i and its interaction energy with the central field created by the nuclear charge and electrons in I-orbitals. The quantity Q_{ij} is the mean interaction energy between an electron in the i^{th} shell and one in the j^{th} shell. The sums in Eqs. (11) and (12) thus go over occupied M and E orbitals, but not over I-orbitals.

We further assume that in a given ion the subconfiguration $\{N_j\} = \{\{N_j'\}_M,\ N_i = 1\}$, where i is an E-orbital and the N_j' are the occupations of M-type shells, has a binding energy ϵ_i that is independent of the distribution $\{N_j'\}_M$ of electrons in M-shells. The energy of this $\{N_j\}$ subconfiguration in the k^{th} ion is

$$E_k\left(\{N_j\}\right) = E_k\left(\{N_j'\}_M\right) + \epsilon_i \quad . \qquad (13)$$

Finally, we make the approximation

$$E_k\left(\{N_j'\}_M\right) = E_{k+1}\left(\{N_j'\}_M\right) \quad , \qquad (14)$$

that is, the energy of the parent subconfiguration $\{N_j'\}_M$ is equal to the energy of the same subconfiguration in the next stage of ionization.

To calculate the energies of ionic states determined by rules a, b, and c, and Table 4, we require only the values of f_i and Q_{ij} for M-orbitals,

and the $\epsilon_{n\ell j}$ for E-orbitals. The Q_{ij} can be expressed as linear combinations of Slater integrals,

$$F_{ij}^{(k)} = 2\ \mathrm{Ry} \int_0^\infty \int_0^\infty P_i^2(r_1)\, P_j^2(r_2)\, \frac{r_<^k}{r_>^{k+1}}\, dr_1 dr_2 \ , \tag{15}$$

$$G_{ij}^{(k)} = 2\ \mathrm{Ry} \int_0^\infty \int_0^\infty P_i(r_1)\, P_j(r_1)\, P_i(r_2)\, P_j(r_2)\, \frac{r_<^k}{r_>^{k+1}}\, dr_1 dr_2 \ , \tag{16}$$

where Ry is the Rydberg unit, $r_<$ ($r_>$) is the lesser (greater) of r_1, r_2, and distances are in atomic units. To a very good approximation, however, we may write simply

$$Q_{ij} = Q = F_{ij}^{(0)} \ , \tag{17}$$

an approximation that we employ in the numerical calculations. We tabulate Slater integrals connecting M-type orbitals in Table 7.

In addition to the Slater integrals, we need the f_i's for the M-type orbitals. Here we do not explicitly calculate expectation values in order to obtain the f_i. Instead, we determine them from the RHFS calculation of the binding energies associated with the various spin-orbitals in the minimum-energy subconfigurations of each ion. Denoting the set of occupation numbers of this subconfiguration in a particular ion by $\{N_i\}^0$, f_k follows from

$$f_k = \epsilon_k\left(\{N_i\}^0\right) - (N_k^0 - 1)\, Q_{kk} - \sum_{j \neq k} N_j^0 Q_{kj} \ . \tag{18}$$

The values of f_k for electrons in M-type orbitals are given in Table 8.

The f_k and Slater integrals allow us to determine the mean energies of the subconfigurations containing no E-electrons from Eq. (11). Of these subconfigurations, we list in Table 9 only those that are considered in

TABLE 7

SLATER INTEGRALS (in Rydbergs)

Slater Integrals	z'											
	1	2	3	4	5	6	7	8	9	10	11	12
$F_0(7s_{1/2}, 7s_{1/2})$	5.7754-01	5.7851-01	6.0271-01	6.2895-01								
$F_0(7s_{1/2}, 6d_{3/2})$	6.2234-01	6.4210-01	6.6806-01	6.9037-01								
G_2	2.5337-01	2.3853-01	2.4545-01	2.6167-01								
$F_0(7s_{1/2}, 5f_{5/2})$	7.2670-01	7.2806-01	7.4958-01	7.7847-01								
G_3	4.9074-02	4.3837-02	5.3635-02	5.6948-02								
$F_0(6p_{1/2}, 6p_{1/2})$						1.2737+00	1.2933+00	1.3053+00	1.3190+00	1.3038+00	1.3222+00	1.3412+00
F_2						6.9989-01	7.1172-01	7.1936-01	7.2790-01	7.2095-01	7.3174-01	7.4284-01
$F_0(6p_{1/2}, 6p_{3/2})$						1.1938+00	1.2150+00	1.2295+00	1.2457+00	1.2350+00	1.2552+00	1.2762+00
F_2						6.4560-01	6.5861-01	6.6806-01	6.7830-01	6.7431-01	6.8638-01	6.9851-01
G_0						1.1150+00	1.1352+00	1.1496+00	1.1654+00	1.1566+00	1.1759+00	1.1957+00
G_2						6.2043-01	6.3288-01	6.4209-01	6.5202-01	6.4849-01	6.6003-01	6.7157-01
$F_0(6p_{1/2}, 5f_{5/2})$						1.3962+00	1.4379+00	1.4437+00	1.4684+00	1.4526+00	1.4705+00	1.4909+00
F_2						6.6133-01	6.6882-01	6.7900-01	6.8394-01	6.7650-01	6.8821-01	6.9965-01
G_2						4.6375-01	4.4286-01	4.5639-01	4.4334-01	4.3549-01	4.4098-01	4.4379-01
G_4						3.4334-01	3.3270-01	3.4261-01	3.3607-01	3.3106-01	3.3658-01	3.4048-01
$F_0(6p_{3/2}, 6p_{3/2})$					1.1095+00	1.1315+00	1.1537+00	1.1698+00	1.1875+00	1.1800+00	1.2016+00	1.2237+00
F_2					6.0982-01	6.2334-01	6.3689-01	6.4708-01	6.5796-01	6.5510-01	6.6753-01	6.7989-01
$F_0(6p_{3/2}, 6d_{3/2})$					9.5604-01							
F_2					4.9273-01							
G_1					5.8888-01							
G_3					3.7073-01							
$F_0(6p_{3/2}, 5f_{5/2})$					1.2529+00	1.2831+00	1.3220+00	1.3329+00	1.3587+00	1.3489+00	1.3703+00	1.3934+00
F_2					5.5628-01	5.6650-01	5.7001-01	5.8387-01	5.8864-01	5.8544-01	5.9919-01	6.1217-01
G_2					3.5058-01	3.4521-01	3.2169-01	3.3552-01	3.2260-01	3.1755-01	3.2269-01	3.2514-01
G_4					2.6404-01	2.6277-01	2.4966-01	2.6029-01	2.5358-01	2.5086-01	2.5632-01	2.6005-01
$F_0(6d_{3/2}, 6d_{3/2})$	6.9930-01	7.6319-01	7.9267-01	8.0190-01	8.5923-01							
F_2	3.5690-01	3.9819-01	4.1978-01	4.2935-01	4.6502-01							
F_4	2.3368-01	2.6355-01	2.8040-01	2.8783-01	3.1423-01							
$F_0(6d_{3/2}, 5f_{5/2})$	8.8318-01	9.4895-01	9.6694-01	9.7415-01	1.0307+00							
F_2	2.8785-01	3.1742-01	3.4464-01	3.4486-01	3.8134-01							
F_4	1.5357-01	1.7018-01	1.9070-01	1.8920-01	2.1299-01							
G_1	1.6911-01	1.7799-01	2.1444-01	2.0516-01	2.2950-01							
G_3	1.2537-01	1.3539-01	1.5979-01	1.5514-01	1.7530-01							
G_5	9.4333-02	1.0292-01	1.2096-01	1.1765-01	1.3360-01							
$F_0(5f_{5/2}, 5f_{5/2})$	1.5566+00	1.6165+00	1.5435+00	1.5578+00	1.5759+00	1.6310+00	1.7301+00	1.7164+00	1.7715+00	1.7558+00	1.7702+00	1.7914+00
F_2	7.7357-01	8.0873-01	7.6718-01	7.7680-01	7.8909-01	8.2226-01	8.7919-01	8.7406-01	9.0626-01	9.0015-01	9.1144-01	9.2569-01
F_4	5.0525-01	5.3017-01	5.0086-01	5.0783-01	6.1679-01	5.4058-01	5.8119-01	5.7808-01	6.0133-01	5.9819-01	6.0654-01	6.1744-01
F_6	3.7161-01	3.9068-01	3.6826-01	3.7362-01	3.8052-01	3.9882-01	4.3010-01	4.2784-01	4.4586-01	4.4366-01	4.5033-01	4.5899-01

TABLE 8

INTERACTION ENERGY WITH CORE OF I ELECTRONS = - f_k
(In Rydbergs)

	i				
z'	7s 1/2	6p 1/2	6p 3/2	6d 3/2	5f 5/2
1	4.0537			4.2941	6.2453
2	3.8340			4.3019	6.2021
3	3.9962			4.5919	6.4809
4	3.9032			4.2396	5.7227
5			10.647	7.9658	10.0550
6		14.184	12.820		12.486
7		13.947	12.660		12.419
8		13.826	12.577		10.831
9		13.747	12.525		12.179
10		13.336	12.200		11.833
11		13.345	12.216		11.764
12		13.301	12.134		11.652

TABLE 9

AVERAGE ENERGIES AND VARIANCES

degen.	$7s_{1/2}$	6d	5f	E EMIN (Rydbergs)	Δ^2E (Rydbergs)^2
			z' = 1		
2.1000+02	2	4	0	2.1075+00	7.4600-03
1.6800+03	2	3	1	9.1552-01	1.1463-02
4.0950+03	2	2	2	2.1301-01	1.9921-02
3.6400+03	2	1	3	0.0000	2.8845-02
1.0010+03	2	0	4	2.7649-01	3.6092-02
5.0400+02	1	5	0	2.2197+00	1.3639-02
5.8800+03	1	4	1	1.1078+00	1.9765-02
2.1840+04	1	3	2	4.8544-01	3.0128-02
3.2760+04	1	2	3	3.5255-01	3.9964-02
2.0020+04	1	1	4	7.0916-01	4.6361-02
4.0040+03	1	0	5	1.5553+00	4.8250-02
2.1000+02	0	6	0	2.3641+00	7.4600-03
3.5280+03	0	5	1	1.3323+00	1.5718-02
1.9110+04	0	4	2	7.9003-01	2.9450-02
4.3680+04	0	3	3	7.3726-01	4.3120-02
4.5045+04	0	2	4	1.1740+00	5.3043-02
2.0020+04	0	1	5	2.1002+00	5.7180-02
3.0030+03	0	0	6	3.5159+00	5.6143-02
			z' = 2		
1.2000+02	2	3	0	2.6250+00	6.5119-03
6.3000+02	2	2	1	1.2682+00	8.3260-03
9.1000+02	2	1	2	3.9322-01	1.5291-02
3.6400+02	2	0	3	0.0000	2.4125-02
4.2000+02	1	4	0	2.5840+00	1.3855-02
3.3600+03	1	3	1	1.3270+00	1.7653-02
8.1900+03	1	2	2	5.5179-01	2.5661-02
7.2800+03	1	1	3	2.5837-01	3.3063-02
2.0020+03	1	0	4	4. 673-01	3.9569-02
2.5200+02	0	5	0	2.6004+00	1.0336-02
2.9400+03	0	4	1	1.4433+00	1.7451-02
1.0920+04	0	3	2	7.6786-01	2.9324-02
1.6380+04	0	2	3	5.7424-01	4.0808-02
1.0010+04	0	1	4	8.6240-01	4.8879-02
2.6920+03	0	0	5	1.6323+00	5.2637-02

degen.	$7s_{1/2}$	6d	5f	E EMIN (Rydbergs)	Δ^2E (Rydbergs)^2
			z' = 3		
4.500+01	2	2	0	3.5539+00	3.2217-03
1.400+02	2	1	1	2.3021+00	1.4685-03
9.100+01	2	0	2	8.5275-01	8.6767-03
2.100+02	1	3	0	3.2727+00	1.1466-02
1.260+03	1	2	1	1.8138+00	1.3882-02
1.820+03	1	1	2	7.5714-01	1.8254-02
7.280+02	1	0	3	1.0283-01	2.1804-02
2.100+02	0	4	0	3.0509-01	1.0355-02
1.680+03	0	3	1	1.6847+00	1.6966-02
4.095+03	0	2	2	7.2079-01	2.5567-02
3.640+03	0	1	3	1.5923-01	3.2263-02
1.001+03	0	0	4	0.0000	3.5496-02
			z' = 4		
1.000+01	2	1	0	2.4596+00	0.0000
1.400+01	2	0	1	1.1517 00	0.0000
9.000+01	1	2	0	2.2951+00	7.0241-03
2.800+02	1	1	1	1.0723+00	6.0157-03
1.820+02	1	0	2	2.6098-01	8.9898-03
1.200+02	0	3	0	2.1816+00	7.5879-03
6.300+02	0	2	1	1.0431+00	1.0327-02
9.100+02	0	1	2	3.1585 01	1.6120-02
3.640+02	0	0	3	0.0000	2.2245-02

degen.	$6p_{3/2}$	6d	5f	E - EMIN (Rydbergs)	Δ^2E (Rydbergs)^2
			z' = 5		
9.100+01	4	0	2	0.0000	9.1853-03
1.400+02	4	1	1	3.5683-01	4.8651-03
4.300+01	4	2	0	1.0874+00	3.9631-03
1.456+03	3	0	3	1.6684+00	7.1590-02
3.640+03	3	1	2	1.7769+00	8.0397-02
2.520+03	3	2	1	2.2591+00	7.9528-02
4.800+02	3	3	0	3.1151+00	7.1602-02

TABLE 9 (continued)

degen.	$6p_{1/2}$	$6p_{3/2}$	5f	E - EMIN (Rydbergs)	$\Delta^2 E$ (Rydbergs)^2
			z' = 6		
1.400+01	2	4	1	0.0000	0.0000
3.640+02	2	3	2	1.5418+00	4.4673-02
1.820+02	1	4	2	2.4125+00	7.0030-02
2.184+03	2	2	3	3.2799+00	9.9748-02
2.912+03	1	3	3	4.0998+00	1.6720-01
3.640+02	0	4	3	4.9373+00	2.4957-02
			z' = 7		
1.000+00	2	4	0	0.0000	0.0000
5.600+01	2	3	1	1.1911+00	1.6825-02
2.800+01	1	4	1	2.0998+00	3.0105-02
5.460+02	2	2	2	2.6220+00	6.4524-02
7.280+02	1	3	2	3.5762+00	1.1056-01
9.100+01	0	4	2	4.3572+00	1.1425-02
			z' = 8		
2.000+00	1	4	0	9.9480-01	0.0000
4.000+00	2	3	0	0.0000	0.0000
8.400+01	2	2	1	2.5005+00	3.6277-02
1.120+02	1	3	1	3.4443+00	6.2853-02
1.400+01	0	4	1	4.4041+00	0.0000
3.640+02	2	1	2	5.2214+00	4.4824-02
1.092+03	1	2	2	6.1141+00	1.4398-01
3.640+02	0	3	2	7.0229+00	4.4824-02
			z' = 9		
6.000+00	2	2	0	0.0000	1.2769-02
8.000+00	1	1	0	1.0319+00	1.3252-02
1.000+00	0	4	0	2.0789+00	0.0000
5.600+01	2	1	1	9.6330-01	1.7147-02
1.680+02	1	2	1	1.9437+00	8.3362-02
5.600+01	0	3	1	2.9392+00	1.7147-02
9.100+01	2	0	2	2.1682+00	1.2150-02
7.280+02	1	1	2	3.0971+00	1.1311-01
5.460+02	0	2	2	4.0411+00	6.6827-02

degen.	$6p_{1/2}$	$6p_{3/2}$	5f	E - EMIN (Rydbergs)	$\Delta^2 E$ (Rydbergs)^2
			z' = 10		
4.000+00	2	1	0	0.0000	0.0000
1.200+01	1	2	0	1.0122+00	2.9822-02
4.000+00	0	3	0	2.0382+00	0.0000
1.400+01	2	0	1	8.0180-01	0.0000
1.120+02	1	1	1	1.7653+00	5.9150-02
8.400+01	0	2	1	2.7426+00	3.4622-02
1.820+02	1	0	2	2.7564+00	6.6204-02
3.640+02	0	1	2	3.6850+00	4.2828-02
			z' = 11		
1.000+00	2	0	0	0.0000	0.0000
8.000+00	1	1	0	1.0624+00	1.3570-02
6.000+00	0	2	0	2.1380+00	1.2834-02
2.800+01	1	0	1	1.7297+00	3.0147-02
5.600+01	0	1	1	2.7587+00	1.7301-02
9.100+01	0	0	2	3.6106+00	1.2297-02
			z' = 12		
2.000+00	1	0	0	0.0000	0.0000
4.000+00	0	1	0	1.1165+00	0.0000
1.400+01	0	0	1	1.6485+00	0.0000

explicit calculations. We also list the energy of these subconfigurations relative to the subconfiguration of minimum mean energy.

Finally, the ϵ's for E-type orbitals are found in Table 4. For n greater than those explicitly appearing in the table, we use the extrapolated defect

$$\mu(\ell j) = \lim_{n \to \infty} \mu(n, \ell, j) \tag{19}$$

and Eq. (1) to calculate the eigenvalue.

From Table 5 we infer that $\mu(n, \ell, j)$ is well approximated by $\mu(\ell, j)$ for relatively small n. For s-, p-, and d-electrons, the limit $\mu(\ell, j)$ is attained to very high accuracy for n = 8 and to within a few percent for n = 7. For f-electrons, the limiting defect is attained at n = 6. We assume that states with $\ell = 4$ are essentially hydrogenic, having a defect near zero. (For E-electrons, we use only the asymptotic defects (see Table 23) in the calculation of partition functions, which are relatively insensitive to the difference between $\mu(\ell, j)$ and μ for the values of n of interest to us here; we do, however, account for this difference in the calculation of oscillator strengths.)

2.3. STATISTICAL ASPECTS OF ATOMIC STATES

As long as the mean degree of ionization in a plasma is sufficiently large, the assignment of a mean energy to each subconfiguration is sufficient to accurately determine the composition and thermodynamic properties of the plasma. This is not the case at low temperatures and large pressures, where neutral uranium constitutes a large fraction of the total number of plasma ions and where only the lowest-lying energy levels in UI are thermally excited. For this case it is necessary to know the detailed level structure of the lowest-lying subconfiguration. For complex ions like UI and UII, the level structure is not well known, and even if it were it would be cumbersome to use such large amounts of information in a flexible computer code.

2.3.1. The Energy Level Distribution Function

The very complexity of an atom makes it possible to describe its level structure in terms of a level density function. Moszkowski[12] has studies level and line distributions that may be expected in complex atoms. Following Moszkowski, we shall adopt the function

$$F(E') = A\left|E' - E_0\right|^m \exp\left[-\frac{(E' - E_0)}{\sigma}\right] \qquad E' > E_0$$

$$= 0 \qquad E' \leq E_0 \qquad (20)$$

for the fraction of states per unit energy in a given subconfiguration. Here A is a normalization constant, leaving three quantities, E_0, σ, and m, to be determined.

Moszkowski has given formulas for the first and second moments of the distribution of term energies in a many-electron configuration. These formulas are expressed in terms of the moments of the distribution of term energies for a two-electron configuration. We will apply his formulas to the problem under consideration here. The expression for the first moment is the mean energy already given in Eq. (11). For the variance $\Delta^2 E(\{N_i\})$ of the subconfiguration with occupation numbers $\{N_i\}$, we write

$$\Delta^2 E\left(\{N_i\}\right) = \sum_i \frac{N_i(N_i - 1)}{2} \frac{M_i - N_i}{M_i - 2} \frac{M_i - N_i - 1}{M_i - 3} \Delta^2 E(ii)$$

$$+ \sum_i \sum_{k>i} \frac{N_i(M_i - N_i)}{M_i - 1} \frac{N_k(M_k - N_k)}{M_k - 1} \Delta^2 E(ik) , \qquad (21)$$

where M_i is the maximum occupation of the i-shell, and $\Delta^2 E(ii)$ and $\Delta^2 E(ik)$ are the variances of two-electron subconfigurations composed of equivalent and nonequivalent electrons, respectively. We have not calculated these variances precisely; instead, we have used the corresponding, more readily

available expressions for two-electron configurations. Values of $\Delta^2 E$ for several subconfigurations in UI - UXII are tabulated in Table 9.

Having the mean energy and variance gives us two relations between the parameters m, σ, and E_0:

$$E = \int_{E_0}^{\infty} F(E')\, E'\, dE' = E_0 + \sigma(m + 1) \tag{22}$$

$$\Delta^2 E = \int_{E_0}^{\infty} F(E')\, (E' - E)^2\, dE' = (m + 1)\sigma^2 \ . \tag{23}$$

To obtain a third relation, we argue as follows. We expect thermodynamic quantities to be insensitive to the form of the distribution function F(E') when many subconfigurations are thermally excited. When only the ground subconfiguration of UI is excited, however, both the translational motion and electronic excitation may contribute significantly to the internal energy of the plasma, and the latter is sensitive to the parameters in F(E'). With these observations in mind, we have chosen m = 0 for all subconfigurations in UII, UIII, etc; in UI we take m the same for all subconfigurations (m = 0.44), choosing it so that the difference between the E_0's for the subconfigurations of lowest energy in UI and UII is equal to the ionization potential from the ground state (I_0 = 6.11 eV of UI).[13]

2.3.2. The Angular Momentum Distribution Function

In addition to the distribution of states with respect to energy, we require the distribution function f(J) for the angular momentum values J within a subconfiguration. To obtain this distribution function, we reason as follows. Suppose that we have a shell $n\ell j$ containing a large number N of electrons, but that N is much less than the maximum number $M = g_{\ell j}$ of electrons that this shell can hold. We further suppose that an electron can occupy any of the 2J+1 magnetic substates independent of the states

occupied by the remaining electrons in the shell. This is a good approximation for $N \ll M$. The total z-component of angular momentum is

$$J_z = m_1 + m_2 + \ldots + m_N \ . \tag{24}$$

If we assume that the m_n are random as well as independent, then by the central limit theorem of statistics we have asymptotically for large N

$$f(J_z) \sim \exp(-\beta J_z^2) \ . \tag{25}$$

Since this form must hold for any of the three components of total angular momentum $\underset{\sim}{J}$, it follows that the distribution function for the total angular momentum J must be

$$f(J) = AJe^{-\beta J^2} \ . \tag{26}$$

In the absence of a more rigorous, yet tractable, analysis of the distribution of angular momentum, we will use Eq. (26) wherever we require the quantity that f(J) is intended to approximate. We will require f(J), in Section 5.7, for example, in order to estimate the number of lines in a transition array.

The quantity A in Eq. (26) is simply a normalization constant:

$$A = 2\beta \ . \tag{27}$$

To obtain β we must relate it to some known property of the distribution. One such property that we can readily evaluate is $(J^2 + J)$, the expectation value of $\underset{\sim}{J}^2$ in a subconfiguration. We have

$$\frac{1}{\beta} + \frac{\sqrt{\pi}}{2\beta^{\frac{1}{2}}} = (J^2 + J)_{av} \ . \tag{28}$$

To calculate $(J^2 + J)_{av}$, we first consider a shell $n\ell j$ containing N electrons. We want to calculate the shell average

$$\langle (A | \underset{\sim}{J}^2 | A) \rangle_{av} \ , \tag{29}$$

where $|A)$ is an N-electron determinantal state composed of one-electron states $|i)$ that are eigenfunctions of $\underset{\sim}{j}_i^2$ and J_{iz}. Observing that

$$\underset{\sim}{J}^2 = \sum_{i=1}^{N} \underset{\sim}{j}_i^2 + \sum_{i=1}^{N} \sum_{k\neq i=1}^{N} \underset{\sim}{j}_i \cdot \underset{\sim}{j}_k \ , \tag{30}$$

we can calculate $(A|\underset{\sim}{J}^2|A)$ using well-known rules[11] for obtaining matrix elements with respect to determinantal states of operators expressible as sums of one- and two-electron operators:

$$\left\langle (A|J^2|A) \right\rangle_{av} = \left\langle \sum_{i=1}^{N} j_i(j_i+1) + \sum_{i=1}^{N} \sum_{k\neq i=1}^{N} \left[(ik|\underset{\sim}{j}_i \cdot \underset{\sim}{j}_k|ik) - (ik|\underset{\sim}{j}_i \cdot \underset{\sim}{j}_k|ki) \right] \right\rangle_{av}$$

$$= Nj(j+1) + \sum_{i} \sum_{k\neq i} \left\langle \left[(ik|\underset{\sim}{j}_i \cdot \underset{\sim}{j}_k|ik) - (ik|\underset{\sim}{j}_i \cdot \underset{\sim}{j}_k|ki) \right] \right\rangle_{av} . \tag{31}$$

To complete the evaluation, we consider

$$\left[(ik|j_{iz}j_{kz}|ik) - (ik|j_{iz}j_{kz}|ki) \right]_{av} = \left\langle m_i m_k - m_i^2 \delta_{ki} \right\rangle_{av} , \tag{32}$$

where m_i is an eigenvalue of j_{iz}. Now

$$\left\langle m_i m_k - m_i^2 \delta_{ki} \right\rangle_{av} = [2j(2j+1)]^{-1} \sum_{m_k=-j}^{j} \sum_{m_i \neq m_k} (m_i m_k - m_i^2 \delta_{ki})$$

$$= -[2j(2j+1)]^{-1} \sum_{m_i=-j}^{j} m_i^2$$

$$= \frac{1}{6j} j(j+1) \tag{33}$$

with identical contributions coming from terms involving the x- and y-components of $\underset{\sim}{j}_i$ and $\underset{\sim}{j}_k$. Finally, since there are N(N - 1) terms in the double sum in Eq. (31), we obtain

$$\left\langle (A|\underset{\sim}{J}^2|A)\right\rangle_{av} = [J(J+1)]_{av} = \frac{N(M-N)}{M-1}\, j(j+1) \ . \tag{34}$$

For more than one $n\ell j$ shell, Eq. (34) generalizes to

$$[J(J+1)]_{av} = \sum_k \frac{N_k(M_k - N_k)}{M_k - 1}\, j_k(j_k+1) \ , \tag{35}$$

the sum going over all shells. Similarly, for $n\ell$ shells, the k^{th} of which contains N_k electrons,

$$[J(J+1)]_{av} = \sum_k \frac{N_k(M_k - N_k)}{M_k - 1}\left[\ell_k(\ell_k+1) + \frac{3}{4}\right] , \tag{36}$$

where now $M_k = 2(2\ell_k + 1)$.

From the distribution function, Eq. (26), we find

$$[J(J+1)]_{av} = \frac{4J_{av}^2}{\pi} + J_{av} \ . \tag{37}$$

Together with Eqs. (35), (36), and (28), this result determines J_{av} and β in terms of the occupation numbers N_k. Having determined J_{av}, we can estimate the number of levels N_{Lev} arising from a given set of occupation numbers N_k by means of

$$(2J_{av} + 1)N_{Lev} = \prod_k \binom{M_k}{N_k} \ , \tag{38}$$

where

$$\binom{M_k}{N_k} = \frac{M_k!}{N_k!(M_k - N_k)} \quad . \tag{39}$$

By explicitly calculating N_{Lev} for several configurations and determining J_{av} from Eq. (38), we find that

$$J_{av} = \frac{\pi}{8}\left[\left\{1 + 4[J(J+1)]_{av}\right\}^{\frac{1}{2}} - 1\right] \tag{40}$$

is a slightly better approximation than the value determined from Eq. (37). In practice, we shall calculate J_{av} from Eq. (40), and use this value in Eq. (38) to estimate N_{Lev}. We have computed the number of levels occurring in an LSJ scheme in a large number of configurations containing two or more electrons. Our approximation for N_{Lev} is in error by less than about 5% for all configurations considered except p^2. In the latter case, the error is about 35%.

3. STATISTICAL MECHANICS

We consider a neutral plasma consisting of ions of a single element and free electrons. In calculating the thermodynamic properties of the plasma we shall take account of the translational motion of the ions and free electrons, the electronic excitation in each ion, and the plasma effect resulting from the electrostatic interaction between the charged particles. We calculate the contribution of electronic excitation to the partition function of the system for all subconfigurations specified by the rules of Sec. 2. 2, accounting for the electrostatic splitting of each of these terms into several energy levels. In estimating the splitting effect we utilize the statistical aspects of atomic spectra described in Sec. 2. 3.

Our treatment of plasma interactions, and the associated effect of the lowering of ionization potentials, has as its basis the theory developed by Stewart and Pyatt.[14] Here, however, we are required to modify this theory while including the plasma effects in calculations of thermodynamic properties, if we are to preserve the relationships that exist among the various thermodynamic quantities.

As our point of departure, we express the Helmholtz free energy F of our system at temperature T and volume V in the form

$$F = -\Theta \sum n_k \ln\left(\frac{e\Lambda_0 Z_k}{n_k}\right) - \Theta n_e \ln\left(\frac{2e\Lambda_e}{n_e}\right) + F_p \ , \qquad (41)$$

where $\Theta = k_B T$ (k_B = Boltzmann's constant),

n_k = the number of ions with charge k times the electronic charge e, and

n_e = the number of free electrons.

The quantities Λ_0 and Λ_e, which originate from the free translational motion of the plasma particles, are given by

$$\Lambda_0 = \frac{(2\pi M\Theta)^{\frac{3}{2}}}{h^3} V \tag{42}$$

$$\Lambda_e = \frac{(2\pi m_e\Theta)^{\frac{3}{2}}}{h^3} V \,, \tag{43}$$

where M is the atomic mass of the element, m_e is the rest mass of an electron, and h is Planck's constant. Finally, Z_k is the electronic partition function:

$$Z_k = \sum_i g_k(i) \exp[-E_k(i)/\Theta] \,, \tag{44}$$

where the sum goes over all levels i of the k^{th} ion, and $g_k(i)$ and $E_k(i)$ are the degeneracy and energy, respectively, of the i^{th} level. F_p in Eq. (41) is the contribution to the free energy from electrostatic interactions between charged plasma particles. Later, we shall give an explicit expression for F_p in terms of the temperature, volume, and the populations of the various species of particles.

3.1. PLASMA EFFECTS

Using a finite-temperature Thomas-Fermi model, Stewart and Pyatt[14] have calculated the average electrostatic potential near a nucleus immersed in a plasma. They also give a simple analytic solution, exhibiting Debye-Hückel and ion-sphere limits, which approximates within about 20% the results of calculations with the full Thomas-Fermi model. This solution is the starting point for our subsequent considerations.

At the position of an ion with ionic charge $z = z' - 1$ Stewart and Pyatt give the average potential resulting from all other charged particles in the system as

$$J(z) = [2(z^* + 1)]^{-1} \{[3(z^* + 1)K(z) + 1]^{\frac{2}{3}} - 1\} , \tag{45}$$

where $J(z)$ is the average potential in units of θ,

$$z^* = \frac{\overline{z^2}}{\overline{z}} = \frac{\sum_k n_k k^2}{n_e} \tag{46}$$

and

$$K(z) = \frac{ze^2}{D\Theta} . \tag{47}$$

The Debye length D is determined from

$$\frac{1}{D^2} = \frac{4\pi e^2}{\Theta} (1 + z^*) \frac{n_e}{V} . \tag{48}$$

The essential assumptions in the determination of this solution are that the nucleus and bound electrons are at a point and have net charge z and that the free-electron density is approximately uniform.

The theory developed by Stewart and Pyatt is not a thermodynamically consistent one. Following the treatment given in Münster's book,[15] let us consider an N-particle plasma in which the charge of the β^{th} ($\beta = 1, \ldots, N$) particle is $a_\beta z_\beta$ ($a_\beta \leq 1$) instead of the full charge z_β that it has in the real plasma. We let $\overline{\Psi}_\alpha(a_j)$ be the electric potential produced at the position of the ion α by all other charged particles. To obtain thermodynamic consistency, we require

$$\frac{\overline{\Psi}_\alpha}{a_\alpha z_\alpha} = \frac{\overline{\Psi}_\beta}{a_\beta z_\beta} = \ldots \tag{49}$$

and

$$z_\alpha \frac{\partial \bar{\Psi}_\alpha}{\partial a_\beta} = z_\beta \frac{\partial \bar{\Psi}_\beta}{\partial a_\alpha} = \ldots . \tag{50}$$

We seek to meet these requirements by first introducing

$$\bar{J} = J(\bar{z}) = \frac{1}{2(z^* + 1)} \left\{ \left[3(1 + z^*) \bar{K} + 1 \right]^{\frac{2}{3}} - 1 \right\} , \tag{51}$$

which differs from J(z) only through the appearance of

$$\bar{K} = \bar{z} \frac{e^2}{D\Theta} \tag{52}$$

in pla ; of K(z) Whereas J(z)Θ represents an average potential at the position of an ion with charge z, $\bar{J}\Theta$ represents the potential at the position of a fictitious ion having an average charge $\bar{z}$. If we also define

$$\mathcal{J}(a_\beta) = \frac{N}{2S(a_\beta)} \left[\left\{ \frac{3e^2}{N\Theta} \left(\frac{4\pi e^2}{\Theta V} \right)^{\frac{1}{2}} [S(a_\beta)]^{\frac{1}{2}} + 1 \right\}^{\frac{2}{3}} - 1 \right] , \tag{53}$$

where

$$S(a_\beta) = a_1^2 z_1^2 + a_2^2 z_2^2 + \ldots + a_N^2 z_N^2 \tag{54}$$

and N is the total number of nuclei in the plasma, we observe that $\bar{z}\,\mathcal{J}(1) = \bar{J}$. By choosing

$$e\bar{\Psi}_\alpha(a_\beta) = - a_\alpha z_\alpha \mathcal{J}(a_\beta) \Theta , \tag{55}$$

we readily verify that the relations (49) and (50) are satisfied.

The plasma contribution to the free energy follows from

$$F_p = e \int_0^1 \sum_\alpha z_\alpha \bar{\Psi}_\alpha(a_\beta)\, da_\alpha . \tag{56}$$

Taking an integration path along which $a_\beta = a$ for all β, we can write

$$F_p = - \Theta \left(\sum{}' n_k k^2 + n_e \right) \int_0^1 \frac{a\bar{J}(a)}{\bar{z}}\, da , \tag{57}$$

where

$$\frac{\overline{J}(a)}{\overline{z}} = \frac{1}{2a^2\,\overline{z}(1+z^*)}\left\{\left[3a^3(1+z^*)\,\overline{K}+1\right]^{\frac{2}{3}}-1\right\}. \tag{58}$$

Explicitly,

$$-\frac{F_p}{\Theta} = \frac{N}{2}\int_0^1 \left\{\left[3a^3(1+z^*)\,\overline{K}+1\right]^{\frac{2}{3}}-1\right\}\frac{da}{a}$$

$$= \frac{N}{2}\int_0^1 \left\{\left[3a^3\,\frac{e^2}{\Theta}\left(\frac{4\pi e^2}{V\Theta}\right)^{\frac{1}{2}}\frac{\left(\sum n_k k^2 + n_e\right)^{\frac{3}{2}}}{N}+1\right]-1\right\}\frac{da}{a}. \tag{59}$$

Having obtained the plasma contribution to the Helmholtz free energy we are in a position to fully determine the equilibrium properties of the plasma. In particular, we obtain the equilibrium composition by insisting that

$$\Omega = F - \sum \mu_k n_k - \mu_e n_e \tag{60}$$

be stationary for arbitrary small variations in n_k and n_e at constant volume and temperature.[15a] In performing these variations in Eq. (60), μ_k and μ_e, the chemical potentials of the k^{th} ionic species and electrons, respectively, play the role of Lagrange multipliers. We may very well expect that this procedure leads to the Saha equation in which appears an effective reduced ionization potential. Since, however, F_p depends on the particle numbers n_k and n_e in a rather complex way, the value that this reduced potential should have is not completely obvious. Therefore, it is worthwhile to explicitly carry out the variational procedure. If we perform the variations and use the condition of macroscopic neutrality to eliminate n_e, the chemical equilibrium conditions

$$\mu_k = \mu_{k+1} + \mu_e \qquad k = 0, 1, 2, \ldots \tag{61}$$

lead to

$$\ln \frac{1}{\Gamma} \frac{Z_k}{Z_{k+1}} \frac{n_{k+1}}{n_k} = - \frac{1}{\Theta} \frac{\partial F_p}{\partial n_{k+1}} - \frac{\partial F_p}{\partial n_k} = (k+1)\frac{\bar{J}}{\bar{z}} = \frac{\Delta E_k}{\Theta} \quad . \tag{62}$$

Introducing

$$U_k = Z_k \exp[E_k(0,0)/\Theta]$$

$$= \sum_i g_k(i) \exp\{-[E_k(i,K) - E_k(0,0)]/\Theta\} \quad , \tag{63}$$

we obtain the Saha equation in the form

$$\frac{n_{k+1}}{n_k} = \Gamma \frac{U_{k+1}}{U_k} \exp[-(I_k - \Delta E_k)/\Theta] \quad , \tag{64}$$

where the ionization potential in the absence of plasma effects,

$$I_k = E_{k+1}(0,0) - E_k(0,0) \quad , \tag{65}$$

is the difference in the ground-state energies of ionic species k+1 and k.

The quantity ΔE_k defined in Eq. (62) is the pressure lowering of the ionization potential. If we examine this quantity, we find that it gives physically plausible results except possibly when $\bar{z} \ll 1$. Two limiting cases are of interest. When

$$3(1+z^*)\,\bar{K} < 1 \quad , \tag{66}$$

we find from Eqs. (51) and (62) that

$$\Delta E_k \approx \frac{k+1}{\bar{z}} K = (k+1)e^2/D\Theta \quad , \tag{67}$$

i. e., the lowering reduces to the Debye limit. This is a proper limit when (66) applies except possibly for a weakly ionized gas ($\bar{z} \ll 1$ and $z^* \approx 1$). For a weakly ionized gas, the Debye limit applies only if

$$e^2/D\Theta < 1 \quad . \tag{68}$$

If, however, $\bar{z} << 1$ and

$$6\frac{\bar{z}e^2}{D\Theta} < 1 \quad , \tag{69}$$

the condition (66) applies, and we obtain the Debye limit even when the condition (68) does not apply. We have not resolved this difficulty, but we do avoid it by an ad hoc method that we describe in Appendix A. For a more complete description of the content of this section, we refer the reader to a forthcoming paper by Pyatt and Parks.[16]

3. 2. ELECTRONIC EXCITATION

The assumptions (a), (b), and (c) of Sec. 2. 2, which together with Table 9 enumerate the subconfigurations that we consider, underlie our calculation of the electronic partition function. According to these assumptions we can express the function U_k for the k^{th} ion in the form

$$U_k = U_k^0 + U_k^1 U_k^E \exp[-I_k/\Theta] \quad , \tag{70}$$

where

$$U_k^0 = \sum_K{}' \phi_k(K) \quad ; \tag{71}$$

here,

$$\phi_k(K) = \sum_s g_k(s,K) \exp\{-[E_k(s,K) - E_k(0,0)]/\Theta\} \quad . \tag{72}$$

The sum in (72) goes over all levels s in the subconfiguration K, the sum in (71) only over subconfigurations having $N-N_I$ electrons in type M spin-orbitals. (These subconfigurations are listed for each ion in Table 9.) The energy of the level s in K is $E_k(s, K)$, its degeneracy is $g_k(s, K)$, and $E_k(0, 0)$ is the energy of the ground state in the k ion. The product term in

Eq. (70) represents the contribution from states with N - (N_I-1) electrons in M-orbitals and one electron in an E-orbital. To obtain U_k^1 we make the approximation

$$U_k^1 = U_{k+1}^0 \ , \tag{73}$$

i. e., the E-electron does not perturb the energy level scheme of the remaining N - (N_I-1) M-electrons. This approximation is consistent with Eq. (14) and the discussion following it.

We obtain U_k^E as the partition function arising from the one-electron E-orbitals:

$$U_k^E = \sum_i g_k(i) \exp\left[-\epsilon_k(i)/\theta\right] \tag{74}$$

the sum going over all E-type orbitals. According to the discussion of Sec. 2. 2, the one-electron levels have energy (in Rydbergs)

$$\epsilon_k(i) = -\frac{(k+1)^2}{\left[n - \mu_{as,\,k}(i)\right]^2} \tag{75}$$

and degeneracy $g_k(i) = (2j_i + 1)$ or $2(2\ell_i + 1)$.

In Appendix A, we evaluate the sum in Eq. (74). In performing the sum, we use the results of Sec. 3. 1 on the lowering of the ionization potential to determine a value of the principal quantum number n at which to terminate it. Moreover, when the energies $\epsilon_k(i)$ are sufficiently closely spaced, we use an integral approximation for the sum.

Let us now consider the part $\phi_k(K)$ of the electronic partition function. To evaluate the sum over states of any function f(E(s, K)) we make the replacement

$$\sum_s g(s,K)\ f(E(s,K)) \rightarrow g(K) \int F_K(E)\ f(E(s,K))\, dE \ , \tag{76}$$

where $F_K(E)$ is the fraction of states in K^{th} subconfiguration of the k^{th} ion having energies between E and E + dE, and g(K) is the degeneracy of the K^{th} subconfiguration. For convenience of notation, we have dropped the ion index k. We find

$$\phi(K) = \sum_s g(s, K) \exp\left\{\frac{-[E(s,K) - E(0,0)]}{\Theta}\right\} \tag{77}$$

$$\rightarrow g(K)\, A(K) \exp\{-[E(0, K) - E(0, 0)]/\Theta\}\left[\frac{1}{\Theta} + \frac{1}{\sigma(K)}\right]^{-m(K)-1} \Gamma[m(K)+1] \quad , \tag{78}$$

where $\Gamma(x)$ is the gamma function. Utilizing the relation (see Eq. (22))

$$E(0, K) = E(K) - \sigma(K)\,[m(K) + 1] \quad , \tag{79}$$

in (78), and remembering that we will take $m_K = m$ to be independent of K, we obtain

$$\phi_k(K) = g_k(K)\left[1 + \frac{\sigma_k(K)}{\Theta}\right]^{-m_k-1} \exp\left[\frac{-\{E_k(K) - E_k(0) - (m_k+1)[\sigma_k(K) - \sigma_k(0)]\}}{\Theta}\right] , \tag{80}$$

where $E_k(0)$ is the mean energy of the ground subconfiguration.

4. THERMODYNAMIC PROPERTIES AND COMPOSITION

The principles and methods of the preceding sections form the essential physical content of a computer program designed to calculate the thermodynamic functions and composition of uranium gas. A brief description of the method of calculation and a summary of the equations used in the program are given in Appendix A.

The program requires the temperature T and the free-electron degeneracy factor Γ, Eq. (A-1), as input quantities. From the curves in Fig. 2 or from Table 10 we can obtain Γ when the pressure and temperature are given. Calculated compositions and thermodynamic functions for the temperature range $5000^{\circ}K \leq T \leq 110,000^{\circ}K$ and the pressure range 100 atm $\leq P \leq$ 1000 atm are presented in Tables 11 and 12, respectively.

At the highest temperatures considered here, the internal energy of the plasma is dominated by the translational energy and the ionization energy, with only small contributions from electronic excitation and plasma effects. Similarly, the pressure is dominated by translational motion with only a small reduction by electrostatic interactions between ions and electrons. At the lower temperatures, the effect of plasma interaction, especially the effect of electronic excitation, may be important. We illustrate this in Table 13,* which gives thermodynamic functions of a uranium plasma at Θ = 1.38 eV and Γ = 83. Electronic excitation contributes approximately 45 percent of the total internal energy, somewhat greater than the relative contribution from either E_{kin} or E_{ion}. The plasma effect reduces the total energy by slightly more than 10 percent and the total pressure by about 15 percent. These results for the plasma effect are typical of the calculated cases for which $\bar{z} \sim 1$.

*The symbols in Table 13 are defined in Appendix A.

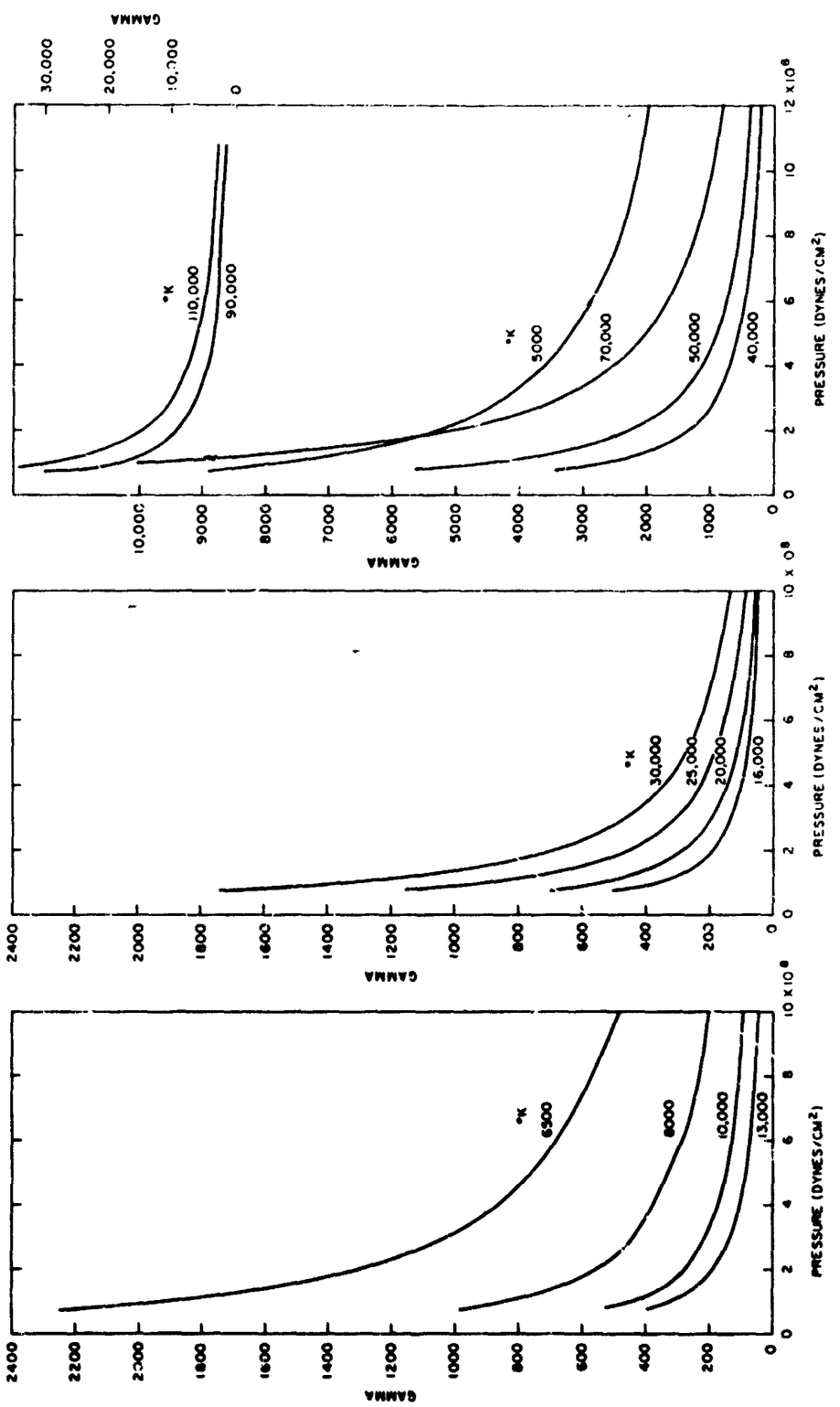


Fig. 2. Γ-P curves at constant temperature.

TABLE 10

FREE ELECTRON DEGENERACY PARAMETER Γ AS FUNCTION OF PRESSURE AND TEMPERATURE

Temperature (°K)	Pressure (dynes/cm^2)	Gamma	Temperature (°K)	Pressure (dynes/cm^2)	Gamma	Temperature (°K)	Pressure (dynes/cm^2)	Gamma	Temperature (°K)	Pressure (dynes cm^2)	Gamma
5,000	1.6493+09	1.0120-03	13,000	1.7449+09	3.2000-01	30,000	2.0160-09	6.5000+01	90,000	2.0202-09	8.9800-02
	1.0167+09	2.1300+03		1.0038+09	5.1000+01		1.0130-09	1.3500-02		1.0137-09	1.8090-03
	6.9336+08	2.6480-03		6.7534+08	7.0060+01		6.7685+08	2.0500-02		6.7565-08	2.7200-03
	5.0521+08	3.1650-03		5.0978-08	8.8000+01		5.0710-08	2.7500-02		5.0739-08	3.6300-03
	3.0317+08	4.2080+03		2.9792+08	1.3700+02		2.9057+08	4.8400-02		2.8980-08	6.3700-03
	2.0309-08	5.2500+03		2.0225-08	1.8600-02		2.0321-08	6.9300-02		2.0282-08	9.1100-03
	1.3909-08	6.4600+03		1.3565-08	2.5600+02		1.3530-08	1.0430-03		1.3521-08	1.3673-04
	1.0148+08	7.6700+03		1.0098+08	3.2500+02		1.0111+08	1.3930-03		1.0137-08	1.8236-04
	7.7441-07	8.8800+03		8.0859-07	3.9500+02		8.0624+07	1.7430-03		8.1066-07	2.2794-04
6,500	1.6600-09	3.6700+02	16,000	1.8461+09	2.3000+01	40,000	2.0197-09	1.2900-02	110,000	2.0211-09	1.4510-03
	1.0156-09	4.9800-02		1.0050+09	4.3000+01		1.0109-09	2.6500-02		1.0138-09	2.9060-03
	6.9551+08	6.2700+02		6.7896+08	6.3000+01		6.7347+08	4.0100-02		6.7026-08	4.3610-03
	5.0910-08	7.5600+02		5.0377+08	8.3000+01		5.0539-08	5.3700-02		5.0719-08	5.8150-03
	3.0307+08	1.0270+03		2.9146-08	1.4000+02		2.8908-08	9.4300-02		2.8925-08	1.0193-04
	2.0301-08	1.2970+03		2.0173+08	1.9700+02		2.0230-08	1.3490-03		2.0237-08	1.4570-04
	1.3887+08	1.6140+03		1.3538+08	2.8700+02		1.3500+08	2.0240+03		1.3542-08	2.1785-04
	1.0153-08	1.9300+03		1.0159-08	3.7600+02		1.0121-02	2.6880-03		1.0180-08	2.9000-04
	7.7656+07	2.2470+03		8.1344+07	4.6600-02		8.1035-07	3.3730-03		8.1574-07	3.6215-04
8,000	1.6767+09	1.4400-02	20,000	1.9802-09	2.6000+01	50,000	2.0574+09	2.1700-02			
	1.0156+09	2.0100-02		1.0190-09	5.5000-01		1.0139-09	4.4600-02			
	6.9062+08	2.5800+02		6.7801+08	8.4000+01		6.7525-08	8.7500+02			
	5.0667+08	3.1400+02		5.0809-08	1.1300-02		5.0517-08	9.0400+02			
	3.0028+08	4.3500+02		2.9053+08	2.0000+02		2.9875+08	1.5880-03			
	2.0179+08	5.5500+02		2.0286+08	2.8600+02		2.0224-08	2.2720-03			
	1.3825+08	6.9900-02		1.3521+08	4.2600+02		1.3523+08	3.3960-03			
	1.0128-08	8.4300+02		1.0150+08	5.6600-02		1.0164-08	4.5200-03			
	7.7822+07	9.8700+02		8.1307+07	7.0600+02		8.1372+07	5.6440-03			
10,000	1.6973+09	6.4000+01	25,000	2.0445+09	4.1000+01	70,000	2.0394+09	4.8700-02			
	1.0140+09	9.3000+01		1.0175-09	8.8000-01		1.0139-09	9.9300-02			
	6.8776+08	1.2200+02		6.7700+08	1.3500-02		6.7604+08	1.4990+03			
	5.0897+08	1.5000+02		5.0805-08	1.8200+02		5.0635+08	2.0050+03			
	2.9860+08	2.1500+02		2.9035+08	3.2200+02		2.8888+08	3.5280-03			
	2.0185+08	2.8000+02		2.0242+08	4.6200+02		2.0215+08	5.0500+03			
	1.3783+08	3.6200+02		1.3457+08	6.9400+02		1.3500+08	7.5650+03			
	1.0132+08	4.4400+02		1.0116+08	9.2600+02		1.0131-08	1.0080+04			
	7.8563+07	5.2600+02		8.0727+07	1.1580+03		8.1052-07	1.2595+04			

TABLE 11
FRACTIONAL POPULATIONS

● (ev)	UI	UII	UIII	UIV	UV	UVI	UVII	UVIII	UIX	UX	UXI	UXII	ZBAR
.43084	9.9847-01	1.5319-03	1.6466-10	1.3739-24	0	0	0	0	0	0	0	0	1.5319-03
.56009	9.8818-01	1.1822-02	2.1376-07	1.0886-17	4.8883-38	0	0	0	0	0	0	0	1.1822-02
.68935	9.5323-01	4.6751-02	2.0675-05	2.4833-13	2.6780-29	0	0	0	0	0	0	0	4.6792-02
.86168	8.3269-01	1.6625-01	1.0614-03	1.3856-09	9.1544-22	0	0	0	0	0	0	0	1.6837-01
1.1202	4.7658-01	4.9105-01	3.2370-02	3.0222-05	5.5791-15	3.9308-29	0	0	0	0	0	0	5.5579-01
1.3787	1.7800-01	6.4845-01	1.7333-01	2.2543-04	5.1129-11	4.4282-22	1.9324-38	0	0	0	0	0	3.9579-01
1.7234	4.7698-02	5.0187-01	4.4473-01	5.7083-03	7.7156-08	2.6869-16	4.4802-29	0	0	0	0	0	1.4084
2.1542	8.3472-03	2.7470-01	6.5532-01	6.1602-02	2.6608-05	1.3739-11	2.2168-21	1.4014-34	0	0	0	0	1.7703
2.5850	1.5895-03	1.1797-01	6.4599-01	2.3332-01	1.1253-03	1.8169-08	3.5012-16	1.5800-26	1.5742-39	0	0	0	2.1144
3.4467	7.8249-05	1.6912-02	2.9916-01	6.1397-01	6.9777-02	9.9664-05	1.1432-09	1.8894-16	4.0885-25	1.3448-35	0	0	2.7363
4.3084	3.0821-06	1.4187-03	8.3082-02	5.0565-01	4.0004-01	9.7974-03	7.1390-06	1.4700-10	1.7287-16	4.5738-24	1.4250-33	0	3.3337
6.0318	2.7479-09	5.1921-06	1.6130-03	8.0140-02	4.7571-01	4.0186-01	4.0842-02	2.2479-04	4.9214-07	3.4184-11	8.0021-17	7.1042-24	4.4004
7.7551	2.1384-12	7.7244-09	4.1510-06	2.3118-03	4.9765-02	3.6744-01	4.7017-01	9.8361-02	1.1875-02	7.3432-05	2.9559-08	9.3665-13	5.0484
9.4785	4.2033-16	2.8884-12	4.1039-09	6.8849-06	6.3598-04	2.1808-02	1.0946-01	3.7996-01	4.3910-01	4.8472-02	5.5686-04	7.2436-07	5.3827

$P = 1.0132+08$ (dynes/cm^2) $= 1.00+02$ (atm)

TABLE 11 (continued)

FRACTIONAL POPULATIONS

Φ(ev)	UI	UII	UIII	UIV	UV	UVI	UVII	UVIII	UIX	UX	UXI	UXII	ZBAR
.43084	9.9888-04	1.1179-03	9.3396-11	6.4548-25	0	0	0	0	0	0	0	0	1.1179-03
.56009	9.9123-01	8.7736-03	1.2921-07	5.8998-18	2.6150-38	0	0	0	0	0	0	0	8.7738-03
.68935	9.6470-01	3.5292-02	1.3118-05	1.4963-13	1.7313-29	0	0	0	0	0	0	0	3.5318-02
.86168	8.7195-01	1.2775-01	6.9678-04	9.0309-10	6.8921-22	0	0	0	0	0	0	0	1.2915-01
1.1202	5.7363-01	4.0437-01	2.2002-02	4.4276-15	4.4260-29	0	0	0	0	0	0	0	4.4838-01
1.3787	2.6351-01	6.0364-01	1.3268-01	1.6851-04	4.5908-11	5.8765-22	4.6639-38	0	0	0	0	0	8.6951-01
1.7834	7.6991-02	5.6886-01	3.5061-01	3.5425-03	4.3564-08	1.5989-16	3.2548-29	0	0	0	0	0	1.2807+00
2.1542	1.5908-02	3.5699-01	5.8905-01	3.8041-02	1.2377-05	5.3351-12	7.9665-22	5.1659-35	0	0	0	0	1.6493+00
2.5890	4.4570-03	1.7835-01	6.6188-01	1.5481-01	5.0643-04	5.9882-09	9.1301-17	3.5221-27	0	0	0	0	1.9686
3.4467	2.8126-04	3.4981-02	4.0607-01	5.2206-01	3.6569-02	3.3301-05	2.5559-10	2.9668-17	4.7336-26	1.2051-36	0	0	2.5598
4.3084	1.4392-05	4.1509-03	1.5037-01	5.7179-01	2.6974-01	3.9403-03	1.7690-06	2.3139-11	1.7[illegible]5-17	3.2439-25	7.1155-35	0	3.1139
6.0318	4.3211-08	3.3244-05	5.4737-03	1.4971-01	5.6030-01	2.6890-01	1.5537-02	4.9234-05	6.3308-08	2.6340-12	3.7672-18	2.1020-25	4.1394
7.7551	5.4996-11	8.2143-08	4.3036-05	8.6167-03	1.1386-01	4.8281-01	3.5168-01	4.0256-02	2.7203-03	9.4853-06	2.1778-09	3.3636-14	5.3032
9.4755	3.1072-14	1.2392-10	1.2373-07	6.4436-05	3.8359-03	7.4975-02	2.2462-01	4.1161-01	2.6848-01	1.5913-02	1.0363-04	7.5205-08	6.9151

P = 2.0265+08 (dynes/cm^2) = 2.00+02 (atm)

TABLE 11 (continued)

FRACTIONAL POPULATIONS

Θ (ev)	UI	UII	UIII	UIV	UV	UVI	UVII	UVIII	UIX	UX	UXI	UXII	ZBAR
.43084	9.9925-01	7.4516-04	4.5848-11	2.5792-25	0	0	0	0	0	0	0	0	7.4516-04
.56009	9.9401-01	5.9875-03	7.0010-08	2.9621-18	1.4198-38	0	0	0	0	0	0	0	5.9877-03
.68935	9.7537-01	2.4618-02	7.6963-06	9.0025-14	1.3024-29	0	0	0	0	0	0	0	2.4633-02
.86168	9.0723-01	9.2327-02	4.4327-04	6.4789-10	7.1462-22	0	0	0	0	0	0	0	9.3214-02
1.1202	6.6976-01	3.1496-01	1.5283-02	1.6816-06	5.9730-15	1.3220-28	0	0	0	0	0	0	3.4553-01
1.3787	3.6452-01	5.3742-01	9.7923-02	1.3946-04	5.9028-11	1.6268-21	3.8521-37	0	0	0	0	0	7.3368-01
1.7234	1.3337-01	5.8869-01	2.7542-01	2.5096-03	3.6493-08	2.0830-16	8.6738-29	0	0	0	0	0	1.1471
2.1542	4.4105-02	4.4270-01	4.9074-01	2.2453-02	6.1705-06	2.7184-13	5.0201-22	4.8715-35	0	0	0	0	1.4916
2.5850	1.3951-02	2.7264-01	6.2014-01	9.3059-02	2.1224-04	2.0112-09	2.8285-17	1.1584-27	0	0	0	0	1.7929
3.4467	1.1764-03	7.7998-02	5.2284-01	3.8265-01	1.5321-02	8.6421-06	4.4882-11	3.8511-18	4.9619-27	1.1144-37	0	0	2.3330
4.3084	9.5959-05	1.5116-02	2.5448-01	5.8081-01	1.4832-01	1.1768-03	3.0436-07	2.4471-12	1.2362-18	1.5451-26	2.5053-36	0	2.8657
6.0318	7.7149-07	2.8770-04	1.8552-02	2.7225-01	5.7221-01	1.3453-01	3.8572-03	6.2500-06	4.2606-09	9.7413-14	7.9381-20	2.6164-27	3.8337
7.7551	2.6163-09	2.1978-06	4.9856-04	3.6021-02	2.5200-01	5.1868-01	1.8253-01	9.8430-03	9.2359-04	5.5888-07	6.5087-11	6.0000-1	4.8778
9.4735	5.1609-12	1.0327-08	3.7063-06	1.1262-03	2.5116-02	2.3671-01	3.5558-01	2.8896-11	8.9923-02	2.5658-03	7.7531-06	2.7221-09	2.18620

$P = 5.0662+08$ (dynes/cm^2) = 5.00+02 (atm)

TABLE 11 (continued)

FRACTIONAL POPULATIONS

Θ(ev)	UI	UII	UIII	UIV	UV	UVI	UVII	UVIII	UIX	UX	UXI	UXII	ZBAR
.43084	9.9945-01	5.5006-04	2.7395-11	1.3681-25	0	0	0	0	0	0	0	0	5.5008-4
.56009	9.9545-01	4.5507-03	4.6514-08	1.9818-18	1.1020-38	0	0	0	0	0	0	0	4.5508-03
.68935	9.8090-01	1.9096-02	5.5364-06	7.2279-14	1.4047-29	0	0	0	0	0	0	0	1.9107-02
.86168	9.2611-01	7.3543-02	3.4723-04	6.2741-10	1.0768-21	0	0	0	0	0	0	0	7.4238-02
1.1202	7.2586-01	2.6102-01	1.3113-02	1.9565-06	1.2508-14	6.6149-23	0	0	0	0	0	0	2.8725-01
1.3787	4.4582-01	4.6520-01	8.8802-02	1.7652-04	1.4492-10	1.0776-20	9.5768-36	0	0	0	0	0	6.4334-01
1.7234	2.0732-01	5.4423-01	2.4578-01	2.6714-03	6.2005-08	7.6026-16	9.1511-28	0	0	0	0	0	1.0438+00
2.1542	7.1413-02	4.7172-01	4.3884-01	1.8022-02	5.3566-06	3.1206-12	9.3193-22	1.7884-34	0	0	0	0	1.4035
2.5850	2.2286-02	3.4458-01	5.6750-01	6.5503-02	1.3227-04	1.2848-09	2.1450-17	1.2094-27	0	0	0	0	1.6766
3.4467	3.7559-03	1.2303-01	5.6810-01	2.9657-01	8.5333-03	3.7655-06	1.6773-11	1.3535-18	1.7983-27	4.5669-38	0	0	2.1931
4.3084	4.8851-04	3.0703-02	3.4567-01	5.3286-01	8.9792-02	4.8574-04	9.1256-08	5.6845-13	2.3731-19	2.6194-27	3.9851-37	0	2.6822
6.0318	4.3690-06	1.0244-03	4.1204-02	3.7450-01	5.0955-01	7.2426-02	1.2900-03	1.3442-06	6.1178-10	9.6919-15	5.6803-21	1.3977-28	3.6150
7.7551	3.9234-08	1.5641-05	2.0083-03	8.4213-02	3.7022-01	4.4764-01	9.2881-02	2.9668-03	5.9515-05	6.4088-08	4.7697-12	2.3805-17	4.5543
9.4785	2.1987-10	1.7394-07	3.4980-05	5.4127-03	6.8888-02	3.8629-01	3.4993-01	1.5967-01	2.9282-02	4.3225-04	8.9018-07	1.9038-10	5.6793

$P = 1.0132+09$ (dynes/cm^2) = 1.00+03 (atm)

TABLE 12 (sheet 1 of 12)

THERMODYNAMIC FUNCTIONS

TEMP	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(K)	(g/cm^3)	(cm^3/g)	(cal/g)	(cal/g/K)	(cal/cm^3)	(cal/g/K)	(cal/g)	(cal/K/g)	
5.0000+3	5.7268-02	1.7462+01	1.1494+02	2.3606-02	4.6382-02	3.2332-02	1.5729+02	2.6190-01	1.5319-03
6.5000+3	4.3713-02	2.2877+01	1.5686+02	3.3189-02	2.6002-01	4.3245-02	2.1237+02	2.7264-01	1.1322-02
8.0000+3	3.4524-02	2.8966+01	2.2512+02	5.6008-02	7.9208-01	7.0013-02	2.9523+02	2.8473-01	4.6792-02
1.0000+4	2.5458-02	3.9280+01	3.9685+02	1.0441-01	1.9672+00	1.3138-01	4.9197+02	3.0640-01	1.6837-01
1.3000+4	1.5617-02	6.4032+01	8.7179+02	1.6230-01	2.9479+00	2.1652-01	1.0263+03	3.5061-01	5.5579-01
1.6000+4	1.0288-02	9.7206+01	1.4375+03	1.5105-01	2.3594+00	2.0962-01	1.6735+03	3.9358-01	9.9579-01
2.0000+4	6.7527-03	1.4809+02	2.0550+03	1.2139-01	1.7400+00	1.7777-01	2.4142+03	4.3516-01	1.4084+00
2.5000+4	4.5893-03	2.1790+02	2.7507+03	1.2756-01	1.4250+00	1.8450-01	3.2775+03	4.7404-01	1.7703+00
3.0000+4	3.3575-03	2.9784+02	3.5847+03	1.5514-01	1.5107+00	2.2273-01	4.3045+03	5.1154-01	2.1144+00
4.0000+4	2.0620-03	4.8496+02	5.4824+03	1.9013-01	1.4293+00	2.6928-01	6.6555+03	5.7900-01	2.7398+00
5.0000+4	1.4121-03	7.0816+02	8.0849+03	2.5742-01	1.5574+00	3.5596-01	9.8052+03	6.4896-01	3.3337+00
7.0000+4	7.9465-04	1.2584+03	1.4981+04	4.1025-01	1.7787+00	5.4867-01	1.8028+04	7.8597-01	4.4004+00
9.0000+4	4.9888-04	2.0045+03	2.5853+04	5.8956-01	2.0396+00	7.8245-01	3.0710+04	9.4460-01	5.4484+00
1.1000+5	3.2431-04	3.0835+03	4.5324+04	7.6769-01	2.0543+00	1.0116+00	5.2826+04	1.1653+00	7.3327+00

P = 1.0132+08 ($dynes/cm^2$) = 1.00+02 (atm)

TEMP = T = temperature in $^{\circ}K$

RHO = ρ = density

TAU = τ = specific volume

E = internal energy

C_v = specific heat at constant volume

DEDTAU = $\left(\frac{\partial E}{\partial v}\right)_T$

C_p = specific heat at constant pressure

ZBAR = $\bar{z}$ = average number of free electrons per ion

TABLE 12 (sheet 2 of 12)

THERMODYNAMIC FUNCTIONS

TEMP	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(R)	(lb/ft^3)	(ft^3/lb)	(BTU/lb)	(BTU/lb/R)	(BTU/ft^3)	(BTU/lb/R)	(BTU/lb)	(BTU/R, LB)	
8.9862+3	3.5752+00	2.7970-01	2.0689+02	2.3642-02	5.2119+01	2.3806-02	2.8312+02	2.5231-01	1.5319-03
1.1682+4	2.7290+00	3.6644-01	2.8234+02	3.3240-02	2.9219+02	3.4215-02	3.8227+02	2.7305-01	1.1822-02
1.4372+4	2.1553+00	4.6397-01	4.0522+02	5.6094-02	8.9006+02	5.9552-02	5.3142+02	2.8516-01	4.6792-02
1.7972+4	1.5894+00	6.2918-01	7.1433+02	1.0457-01	2.2105+03	1.1667-01	8.8555+02	3.0688-01	1.6837-01
2.3364+4	9.7498-01	1.0257+00	1.5692+03	1.6255-01	3.3126+03	1.9276-01	1.8474+03	3.5114-01	5.5579-01
2.8756+4	6.4225-01	1.5570+00	2.5875+03	1.5128-01	2.6513+03	1.8013-01	3.0123+03	3.9419-01	9.9579-01
3.5945+4	4.2157-01	2.3721+00	3.6990+03	1.2157-01	1.9553+03	1.4509-01	4.3456+03	4.3583-01	1.4084+00
4.4931+4	2.8651-01	3.4903+00	4.9513+03	1.2775-01	1.6013+03	1.4889-01	5.8996+03	4.7478-01	1.7703+00
5.3917+4	2.0961-01	4.7707+00	6.4525+03	1.5538-01	1.6976+03	1.8142-01	7.7481+03	5.1232-01	2.1144+00
7.1890+4	1.2873-01	7.7680+00	9.8683+03	1.9042-01	1.6061+03	2.1986-01	1.1980+04	5.7989-01	2.7368+00
8.9862+4	8.8158-02	1.1343+01	1.4553+04	2.5781-01	1.7500+03	2.9637-01	1.7649+04	6.4096-01	3.3337+00
1.2581+5	4.9610-02	2.0157+01	2.6967+04	4.1088-01	1.9987+03	4.6959-01	3.2451+04	7.8716-01	4.4004+00
1.6175+5	3.1145-02	3.2108+01	4.6536+04	5.9046-01	2.2918+03	6.7877-01	5.5278+04	9.4606-01	5.6484+00
1.9770+5	2.0247-02	4.9391+01	8.1583+04	7.6887-01	2.3084+03	8.8071-01	9.5087+04	1.1671+00	7.3827+00

P = 1.0132+08 ($dynes/cm^2$) = 1.00+02 (atm)

TABLE 12 (sheet 3 of 12)

THERMODYNAMIC FUNCTIONS

THETA	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(ev)	(g/cm^3)	(cm^3/g)	(erg/g)	(erg/g/ev)	(erg/cm^3)	(erg/g/ev)	(erg/g)	(erg/ev g)	
.43084	5.7268-02	1.7462+01	4.8090+09	1.1462+10	1.9406+06	1.5699+10	6.5810+09	1.2717+11	1.5310-03
.56009	4.3713-02	2.2877+01	6.5629+09	1.1612+10	1.0879+07	2.0998+10	8.8855+09	1.3238+11	1.1822-02
.68935	3.4524-02	2.8966+01	9.4190+09	2.7195+10	3.3141+07	3.3996+10	1.2353+10	1.3825+11	4.6792-02
.86168	2.5458-02	3.9280+01	1.6604+10	5.0695+10	8.2307+07	6.3791+10	2.0584+10	1.4878+11	1.0837-01
1.1202	1.5617-02	6.4032+01	3.6476+10	7.8805+10	1.2334+08	1.0513+11	4.2942+10	1.7024+11	5.5579-01
1.3787	1.0288-02	9.7206+01	6.0145+10	7.3344+10	9.8717+07	1.0178+11	7.0020+10	1.9111+11	9.9579-01
1.7234	6.7527-03	1.4809+02	8.5981+10	5.8942+10	7.2805+07	8.6317+10	1.0101+11	2.1130+11	1.4084+00
2.1542	4.5893-03	2.1790+02	1.1509+11	6.1936+10	5.9624+07	8.9588+10	1.3713+11	2.3018+11	1.7703+00
2.5850	3.3575-03	2.9784+02	1.4998+11	7.5329+10	6.3209+07	1.0815+11	1.8010+11	2.4838+11	2.1144+00
3.4467	2.0620-03	4.8496+02	2.2938+11	9.2319+10	5.9801+07	1.3075+11	2.7846+11	2.8114+11	2.7368+00
4.3084	1.4121-03	7.0816+02	3.3827+11	1.2499+11	6.5161+07	1.7284+11	4.1025+11	3.1511+11	3.3337+00
6.0318	7.9465-04	1.2584+03	6.2682+11	1.9920+11	7.4419+07	2.6641+11	7.5431+11	3.8163+11	4.4004+00
7.7551	4.9888-04	2.0045+03	1.0817+12	2.8627+11	8.5335+07	3.7993+11	1.2849+12	4.5866+11	5.6484+00
9.4785	3.2431-04	3.0835+03	1.8963+12	3.7276+11	8.5951+07	4.9120+11	2.2102+12	5.6581+11	7.3827+00

P = 1.0132+08 ($dynes/cm^2$) = 1.00+02 (atm)

TABLE 12 (sheet 4 of 12)

THERMODYNAMIC FUNCTIONS

TEMP	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(K)	(g/cm^3)	(cm^3/g)	(cal/g)	(cal/g/K)	(cal/cm^3)	(cal/g/K)	(cal/g)	(cal/K/g)	
5.0000+3	1.1465-01	8.7220+00	1.1465+02	2.3147-02	6.6003-02	3.1796-02	1.5699+02	2.5637-01	1.1179-03
6.5000+3	8.7645-02	1.1410+01	1.5475+02	3.1120-02	3.7216-01	4.0707-02	2.1012+02	2.6703-01	8.7738-03
8.0000+3	6.9475-02	1.4394+01	2.1537+02	4.8855-02	1.1538+00	6.1202-02	2.8479+02	2.7824-01	3.5318-02
1.0000+4	5.2632-02	1.9000+01	3.6497+02	9.0142-02	3.0253+00	1.1143-01	4.5708+02	2.9748-01	1.2915-01
1.3000+4	3.3826-02	2.9563+01	7.7347+02	1.4367-01	5.3801+00	1.8787-01	9.1638+02	3.3532-01	4.4838-01
1.6000+4	2.2486-02	4.4471+01	1.2882+03	1.4050-01	4.8617+00	1.9474-01	1.5026+03	3.7300-01	8.6951-01
2.0000+4	1.4697-02	6.8043+01	1.8898+03	1.1529-01	3.6179+00	1.6877-01	2.2197+03	4.1321-01	1.2807+00
2.5000+4	9.8733-03	1.0128+02	2.5432+03	1.4765-01	2.9460+00	1.6931-01	3.0333+03	4.4965-01	1.6493+00
3.0000+4	7.2491-03	1.3795+02	3.2838+03	1.3783-01	2.9959+00	2.0039-01	3.9538+03	4.8320-01	1.9686+00
4.0000+4	4.4092-03	2.2680+02	5.0055+03	1.6637-01	2.9113+00	2.4182-01	6.1020+03	5.4504-01	2.5598+00
5.0000+4	3.0028-03	3.3302+02	7.3361+03	2.3801-01	3.2015+00	3.3300-01	8.9458+03	6.0847-01	3.1139+00
7.0000+4	1.6862-03	5.9305+02	1.3534+04	3.4881-01	3.3231+00	4.7258-01	1.6399+04	7.3311-01	4.1394+00
9.0000+4	1.0624-03	9.4123+02	2.3237+04	4.8151-01	3.7477+00	6.5020-01	2.7800+04	8.7562-01	5.3092+00
1.1000+5	6.8915-04	1.4511+03	4.0421+04	8.7577-01	5.3446+00	1.1745+00	4.7439+04	1.0706+00	6.9151+00

P = 2.0265+08 ($dynes/cm^2$) = 2.00+02 (atm)

TABLE 12 (sheet 5 of 12)

THERMODYNAMIC FUNCTIONS

TEMP	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(R)	(lb/ft^3)	(ft^3/lb)	(BTU/lb)	(BTU/lb/R)	(BTU/ft^3)	(BTU/lb/R)	(BTU/lb)	(BTU/R/LB)	
8.9862+3	7.1577+00	1.3971-01	2.0638+02	2.3182-02	7.4168+01	3.1845-02	2.8258+02	2.5678-01	1.1179-03
1.1682+4	5.4716+00	1.8276-01	2.7856+02	3.1168-02	4.1819+02	4.0769-02	3.7821+02	2.6744-01	8.7738-03
1.4378+4	4.3373+00	2.3056-01	3.8767+02	4.8930-02	1.2965+03	6.1296-02	5.1262+02	2.7866-01	3.5318-02
1.7972+4	3.2858+00	3.0434-01	6.5694+02	9.0281-02	3.3995+03	1.1160-01	8.2275+02	2.9793-01	1.2915-01
2.3364+4	2.1117+00	4.7355-01	1.3922+03	1.4389-01	6.0456+03	1.8816-01	1.6495+03	3.3584-01	4.4838-01
2.8756+4	1.4038+00	7.1234-01	2.3187+03	1.4071-01	5.4631+03	1.9504-01	2.7047+03	3.7356-01	8.6951-01
3.5945+4	9.1751-01	1.0899+00	3.4017+03	1.1546-01	4.0655+03	1.6903-01	3.9955+03	4.1385-01	1.2807+00
4.4931+4	6.1639-01	1.6223+00	4.5779+03	1.1494-01	3.3104+03	1.6957-01	5.4599+03	4.5033-01	1.6493+00
5.3917+4	4.5256-01	2.2096+00	5.9109+03	1.3804-01	3.3665+03	2.0069-01	7.1169+03	4.8395-01	1.9686+00
7.1890+4	2.7527-01	3.6328+00	9.0098+03	1.6662-01	3.2714+03	2.4219-01	1.0984+04	5.4588-01	2.5598+00
8.9862+4	1.8746-01	5.3343+00	1.3205+04	2.3838-01	3.5976+03	3.3351-01	1.6103+04	6.0940-01	3.1189+00
1.2581+5	1.0527-01	9.4995+00	2.4361+04	3.4934-01	3.7342+03	4.7330-01	2.9518+04	7.3423-01	4.1394+00
1.6175+5	6.6328-02	1.5077+01	4.1827+04	4.8225-01	4.2113+03	6.5120-01	5.0040+04	8.7695-01	5.3092+00
1.9770+5	4.3024-02	2.3243+01	7.2757+04	8.7712-01	6.0053+03	1.1763+00	8.5390+04	1.0722+00	6.9151+00

P = 2.0265+08 ($dynes/cm^2$) = 2.00+02 (atm)

TABLE 12 (sheet 6 of 12)

THERMODYNAMIC FUNCTIONS

THETA	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(ev)	(g/cm^3)	(cm^3/g)	(erg/g)	(erg/g/ev)	(erg/cm^3)	(erg/g/ev)	(erg/g)	(erg/ev/g)	
.43084	1.1465-01	8.7220+00	4.7971+09	1.1239+10	2.7616+06	1.5439+10	6.5684+09	1.2449+11	1.1179-03
.56009	8.7645-02	1.1410+01	6.4749+09	1.5111+10	1.5571+07	1.9766+10	8.7912+09	1.2966+11	8.7738-03
.68935	6.9475-02	1.4394+01	9.0112+09	2.3722+10	4.8274+07	2.9717+10	1.1916+10	1.3510+11	3.5318-02
.86168	5.2632-02	1.9000+01	1.5270+10	4.3770+10	1.2658+08	5.4108+10	1.9124+10	1.4444+11	1.2915-01
1.1202	3.3826-02	2.9563+01	3.2362+10	6.9762+10	2.2517+08	9.1224+10	3.8341+10	1.6282+11	4.4838-01
1.3787	2.2486-02	4.4471+01	5.3898+10	6.8221+10	2.0341+08	9.4560+10	6.2869+10	1.8111+11	8.6951-01
1.7234	1.4697-02	6.8043+01	7.9071+10	5.5979+10	1.5137+08	8.1951+10	9.2873+10	2.0064+11	1.2807+00
2.1542	9.8733-03	1.0128+02	1.0641+11	5.5725+10	1.2326+08	8.2210+10	1.2691+11	2.1833+11	1.6493+00
2.5850	7.2491-03	1.3795+02	1.3740+11	6.6924+10	1.2535+08	9.7300+10	1.6543+11	2.3463+11	1.9686+00
3.4467	4.4092-03	2.2680+02	2.0943+11	8.0782+10	1.2181+08	1.1742+11	2.5531+11	2.6465+11	2.5598+00
4.3084	3.0028-03	3.3302+02	3.0694+11	1.1557+11	1.3395+08	1.6169+11	3.7429+11	2.9545+11	3.1189+00
6.0318	1.6862-03	5.9305+02	5.6625+11	1.6937+11	1.3904+08	2.2946+11	6.8613+11	3.5597+11	4.1394+00
7.7551	1.0624-03	9.4123+02	9.7226+11	2.3380+11	1.5680+08	3.1571+11	1.1632+12	4.2516+11	5.3092+00
9.4785	6.8915-04	1.4511+03	1.6912+12	4.2524+11	2.2362+08	5.7029+11	1.9848+12	5.1982+11	6.9150+00

P = 2.0265+08 (dynes/cm^2) = 2.00+02 (atm)

TABLE 12 (sheet 7 of 12)

THERMODYNAMIC FUNCTIONS

TEMP	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(K)	(g/cm^3)	(cm^3/g)	(cal/g)	(cal/g/K)	(cal/cm^3)	(cal/g/K)	(cal/g)	(cal/K/g)	
5.0000+3	2.8531-01	3.5050+00	1.1440+02	2.2736-02	1.0496-01	3.1316-02	1.5672+02	2.4926-01	7.4516-04
6.5000+3	2.2033-01	4.5386+00	1.5268+02	2.8979-02	5.9736-01	3.8151-02	2.0790+02	2.5992-01	5.9877-03
8.0000+3	1.7606-01	5.6798+00	2.0765+02	4.3495-02	1.8762+00	5.4376-02	2.7643+02	2.7062-01	2.4633-02
1.0000+4	1.3612-01	7.3466+00	3.3086+02	7.3906-02	5.2144+00	9.0328-02	4.2023+02	2.8711-01	9.3214-02
1.3000+4	9.2775-02	1.0779+01	6.5904+02	1.1796-01	1.1060+01	1.5062-01	7.9037+02	3.1748-01	3.4553-01
1.6000+4	6.3252-02	1.5810+01	1.1155+03	1.2722-01	1.1864+01	1.7364-01	1.3058+03	3.4972-01	7.3368-01
2.0000+4	4.1530-02	2.4079+01	1.6677+03	1.0789-01	9.7460+00	1.5854-01	1.9601+03	3.8507-01	1.1471+00
2.5000+4	2.7713-02	3.6084+01	2.2676+03	1.0219-01	8.0873+00	1.5487-01	2.7057+03	4.1868-01	1.4916+00
3.0000+4	2.0057-02	4.9857+01	2.9024+03	1.1542-01	7.6399+00	1.7327-01	3.5067+03	4.4801-01	1.7929+00
4.0000+4	1.2153-02	8.2283+01	4.4221+03	1.4344-01	7.4965+00	2.1384-01	5.4160+03	5.0330-01	2.3330+00
5.0000+4	8.2138-03	1.2175+02	6.4010+03	2.0380-01	8.0322+00	2.9134-01	7.8709+03	5.5785-01	2.8657+00
7.0000+4	4.5856-03	2.1808+02	1.1895+04	2.8136-01	7.6599+00	3.8874-01	1.4534+04	6.6963-01	3.8337+00
9.0000+4	2.9022-03	3.4457+02	2.0140+04	4.1372-01	9.4031+00	5.6954-01	2.4319+04	7.9181-01	4.8777+00
1.1000+5	1.9302-03	5.1809+02	3.3129+04	8.0700-01	1.4804+01	1.1057+00	3.9409+04	9.4149-01	6.1962+00

P = 5.0662+08 ($dynes/cm^2$) = 5.00+02 (atm)

TABLE 12 (sheet 8 of 12)

THERMODYNAMIC FUNCTIONS

TEMP	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(R)	(lb/ft^3)	(ft^3/lb)	(BTU/lb)	(BTU/lb/R)	(BTU/ft^3)	(BTU/lb/R)	(BTU/lb)	(BTU/R/LB)	
8.9862+3	1.7812+01	5.6142-02	2.0592+02	2.2770-02	1.1794+02	3.1364-02	2.8210+02	2.4964-01	7.4516-04
1.1682+4	1.3755+01	7.2700-02	2.7482+02	2.9023-02	6.7125+02	3.8210-02	3.7422+02	2.6032-01	5.9877-03
1.4378+4	1.0992+01	9.0978-02	3.7377+02	4.3561-02	2.1083+03	5.4460-02	4.9757+02	2.7103-01	2.4633-02
1.7972+4	8.4976+00	1.1768-01	5.9554+02	7.4020-02	5.8594+03	9.0466-02	7.5641+02	2.8755-01	9.3214-02
2.3364+4	5.7920+00	1.7265-01	1.1863+03	1.1814-01	1.2428+04	1.5085-01	1.4227+03	3.1795-01	3.4553-01
2.8756+4	3.9488+00	2.5323-01	2.0079+03	1.2742-01	1.3332+04	1.7391-01	2.3505+03	3.5026-01	7.3368-01
3.5945+4	2.5927+00	3.8570-01	3.0018+03	1.0805-01	1.0952+04	1.5878-01	3.5282+03	3.8565-01	1.1471+00
4.4931+4	1.7301+00	5.7799-01	4.0816+03	1.0234-01	9.0877+03	1.5510-01	4.8703+03	4.1933-01	1.4916+00
5.3917+4	1.2521+00	7.9862-01	5.2244+03	1.1560-01	8.5849+03	1.7354-01	6.3121+03	4.4870-01	1.7929+00
7.1890+4	7.5872-01	1.3180+00	7.9598+03	1.4366-01	8.4238+03	2.1416-01	9.7488+03	5.0407-01	2.3330+00
8.9862+4	5.1279-01	1.9501+00	1.1522+04	2.0411-01	9.0258+03	2.9179-01	1.4167+04	5.5870-01	2.8657+00
1.2581+5	2.8628-01	3.4931+00	2.1411+04	2.8179-01	8.6074+03	3.8934-01	2.6162+04	6.7066-01	3.8337+00
1.6175+5	1.8118-01	5.5193+00	3.6253+04	4.1436-01	1.0566+04	5.7041-01	4.3774+04	7.9302-01	4.8778+00
1.9770+5	1.2050-01	8.2987+00	5.9632+04	8.0824-01	1.6635+04	1.1074+00	7.0936+04	9.4293-01	6.1862+00

P = 5.0662+08 ($dynes/cm^2$) = 5.00+02 (atm)

TABLE 12 (sheet 9 of 12)

THERMODYNAMIC FUNCTIONS

THETA	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(ev)	(g/cm^3)	(cm^3/g)	(erg/g)	(erg/g/ev)	(erg/cm^3)	(erg/g/ev)	(erg/g)	(erg/ev/g)	
.43084	2.8531-01	3.5050+00	4.7864+09	1.1040+10	4.3914+06	1.5206+10	6.5571+09	1.2103+11	7.4516-04
.56009	2.2033-01	4.5386+00	6.3879+09	1.4071+10	2.4994+07	1.8525+10	8.6985+09	1.2621+11	5.9877-03
.68935	1.7606-01	5.6798+00	8.6880+09	2.1119+10	7.8500+07	2.6403+10	1.1566+10	1.3140+11	2.4633-02
.86168	1.3612-01	7.3466+00	1.3843+10	3.5886+10	2.1817+08	4.3860+10	1.7582+10	1.3941+11	9.3214-02
1.1202	9.2775-02	1.0779+01	2.7574+10	5.7279+10	4.6275+08	7.3133+10	3.3069+10	1.5415+11	3.4553-01
1.3787	6.3250-02	1.5810+01	4.6672+10	6.1773+10	4.9640+08	8.4315+10	5.4636+10	1.6981+11	7.3368-01
1.7234	4.1530-02	2.4079+01	6.9776+10	5.2386+10	4.0777+08	7.6979+10	8.2010+10	1.3c97+11	1.1471+00
2.1542	2.7713-02	3.6084+01	9.4875+10	4.9618+10	3.3837+08	7.5197+10	1.1321+11	2.0330+11	1.[illegible]
2.5850	2.0057-02	4.9858+01	1.2144+11	5.6044+10	3.1965+08	8.4134+10	1.4672+11	2.1754+11	1.7029+00
3.4467	1.2153-02	8.2283+01	1.8502+11	6.9649+10	3.1365+08	1.0383+11	2.2661+11	2.4438+11	2.3330+00
4.3084	8.2138-03	1.2175+02	2.6782+11	9.8956+10	3.3607+08	1.4146+11	3.2932+11	2.7087+11	2.8657+00
6.0318	4.5856-03	2.1808+02	4.9769+11	1.3662+11	3.2049+08	1.8876+11	6.0811+11	3.2515+11	3.[illegible]+00
7.7551	2.9022-03	3.4457+02	8.4268+11	2.0089+11	3.9343+08	2.7654+11	1.0175+12	3.8447+11	4.3[illegible]+00
9.4785	1.9302-03	5.1809+02	1.3861+12	3.9185+11	6.1941+08	5.3687+11	1.6489+12	4.5715+11	6.1862+00

P = 5.0662+08 ($dynes/cm^2$) = 5.00+02 (atm)

TABLE 12 (sheet 10 of 12)

THERMODYNAMIC FUNCTIONS

TEMP	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(K)	(g/cm^3)	(cm^3/g)	(cal/g)	(cal/g/K)	(cal/cm^3)	(cal/g/K)	(cal/g)	(cal/K/g)	
5.0000+3	5.7230-01	1.7413+00	1.1427+02	2.2530-02	1.4986-01	3.1084-02	1.5659+02	2.4392-01	5.0082-04
6.5000+3	4.0085-01	2.2723+00	1.5165+02	2.7950-02	8.4972-01	3.6916-02	2.0681+02	2.5486-01	4.5508-03
8.0000+3	3.5460-01	2.8201+00	1.8307+02	4.0137-02	2.6863+00	5.0295-02	2.7152+02	2.6534-01	1.9107-02
1.0000+4	2.7566-01	3.6276+00	2.1512+02	6.6305-02	7.5641+00	8.0254-02	4.0303+02	2.8091-01	7.4238-02
1.3000+4	1.9256-01	5.1932+00	6.0001+02	1.C21[illegible]-01	1.7115+01	1.2736-01	7.2460+02	3.0747-01	2.8725-01
1.6000+4	1.39[illegible]4-01	7.1820+00	9.9646+02	1.1182-01	2.1003+01	1.4965-01	1.1689+03	3.3421-01	6.4334-01
2.0000+4	9.3767-01	1.0665+01	1.4948+03	9.8618-02	2.0440+01	1.4593-01	1.7546+03	3.6459-01	1.0438+00
2.5000+4	6.0912-02	1.6417+01	2.0662+03	9.4198-02	1.7241+01	1.4529-01	2.4654+03	3.9640-01	1.4035+00
3.0000+4	4.3691-02	2.2888+01	2.6603+03	1.0295-01	1.5437+01	1.5695-01	3.2144+03	4.2443-01	1.6766+00
4.0000+4	2.6318-02	3.8000+01	3.9993+03	1.2782-01	1.5353+01	1.9442-01	4.9173+03	4.7350-01	2.1831+00
5.0000+4	1.[illegible]787+02	5.6220+01	5.7469+[illegible]	1.7696-01	1.6083+01	2.5840-01	7.1093+03	5.2218-01	2.6822+00
7.0000+4	9.8191-03	1.0184+02	1.0792+04	3.4766-01	1.5178+01	3.4783-01	1.3260+04	6.2553-01	3.6150+00
9.0000+4	6.2372-03	1.6033+02	1.7967+0[illegible]	3.7430-01	1.9074+01	5.2175-01	2.1852+04	7.3297-01	4.5543+00
1.1000+5	4.2071-03	2.3769+02	2.8393+04	6.2326-01	2.5824+01	8.6093-01	3.4153+04	8.5536-01	5.6793+00

P = 1.0132+[illegible] (dynes/cm^2) = 1.00+03 (atm)

TABLE 12 (sheet 11 of 12)

THERMODYNAMIC FUNCTIONS

TEMP	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(R)	(lb/ft^3)	(ft^3/lb)	(BTU/lb)	(BTU/lb/R)	(BTU/ft^3)	(BTU/lb/R)	(BTU/lb)	(BTU/R/LB)	
8.9862+3	3.5853+01	2.7892-02	2.0569+02	2.2573-02	1.6839+02	3.1131-02	2.8185+02	2.4430-01	5.5008-04
1.1682+4	2.7475+01	3.6397-02	2.7297+02	2.7993-02	9.5483+02	3.6972-02	3.7225+02	2.5525-01	4.5508-03
1.4378+4	2.2137+01	4.5172-02	3.6553+02	4.0198-02	3.0186+03	5.0372-02	4.8874+02	2.6575-01	1.9107-02
1.7972+4	1.7210+01	5.8110-02	5.6721+02	6.6407-02	8.4998+03	8.0377-02	7.2545+02	2.8134-01	7.4238-02
2.3364+4	1.2021+01	8.3185-02	1.0800+03	1.0226-01	1.9232+04	1.2756-01	1.3043+03	3.0795-01	2.8725-01
2.8756+4	8.6926+00	1.1504-01	1.7936+03	1.1200-01	2.3601+04	1.4988-01	2.1041+03	3.3472-01	6.4334-01
3.5945+4	5.8539+00	1.7083-01	2.6907+03	9.8769-02	2.2968+04	1.4616-01	3.1582+03	3.6516-01	1.0438+00
4.4931+4	3.8028+00	2.6297-01	3.7191+03	9.4343-02	1.937 +04	1.4551-01	4.4377+03	3.9710-01	1.4035+00
5.3917+4	2.7277+00	3.6661-01	4.7885+03	1.0311-01	1.7346+04	1.5719-01	5.7860+03	4.2509-01	1.6766+00
7.1890+4	1.6430+00	6.0863-01	7.1988+03	1.2802-01	1.7252+04	1.9472-01	8.8512+03	4.7420-01	2.1831+00
8.9862+4	1.1105+00	9.0053-01	1.0344+04	1.7723-01	1.8072+04	2.5879-01	1.2797+04	5.2298-01	2.6822+00
1.2581+5	6.1301-01	1.6313+00	1.9426+04	2.4804-01	1.7055+04	3.4837-01	2.3869+04	6.2648-01	3.6150+00
1.6[illegible]5	3.8939-01	2.5681+00	3.2341+04	3.7488-01	2.1434+04	5.2255-01	3.9333+04	7.3409-01	4.5543+00
1.9770+5	2.6265-01	3.8073+00	5.1108+04	6.2416-01	2.9019+04	8.6225-01	6.1475+04	8.5667-01	5.6793+00

P = 1.0132+09 ($dynes/cm^2$) = 1.00+03 (atm)

TABLE 12 (sheet 12 of 12)

THERMODYNAMIC FUNCTIONS

THETA	RHO	TAU	E	C_v	DEDTAU	C_p	ENTHALPY	ENTROPY	ZBAR
(ev)	(g/cm^3)	(cm^3/g)	(erg/g)	(erg/g/ev)	(erg/cm^3)	(erg/g/ev)	(erg/g)	(erg/ev/g)	
.43084	5.7429-01	1.7413+00	4.7811+09	1.0944+10	6.2700+06	1.5093+10	6.5515+09	1.1844+11	5.5008-04
.56009	4.4009-01	2.2723+00	6.3450+09	1.3572+10	3.5552+07	1.7925+10	8.6527+09	1.2375+11	4.5508-03
.68935	3.5460-01	2.8201+00	8.4965+09	1.9500+10	1.1240+08	2.4421+10	1.1361+10	1.2884+11	1.9107-02
.86168	2.7566-01	3.6276+00	1.3184+10	3.2195+10	3.1648+08	3.8968+10	1.6863+10	1.3640+11	7.4238-02
1.1202	1.9256-01	5.1932+00	2.5104+10	4.9577+10	7.1609+08	6.1843+10	3.0317+10	1.4930+11	2.8725-01
1.3787	1.3924-01	7.1820+00	4.1700+10	5.4397+10	8.7877+08	7.2664+10	4.8910+10	1.6228+11	6.4334-01
1.7234	9.3767-02	1.0665+01	6.2544+10	4.7885+10	8.5521+08	7.0859+10	7.3412+10	1.7703+11	1.0438+00
2.1542	6.0912-02	1.6417+01	8.6448+10	4.5739+10	7.2137+08	7.0547+10	1.0315+11	1.9252+11	1.4035+00
2.5850	4.3692-02	2.2888+01	1.1131+11	4.4588+08	6.4588+08	7.6208+10	1.3449+11	2.0609+11	1.6766+00
3.4467	2.6318-02	3.7997+01	1.6733+11	6.2065+10	6.4236+08	9.4404+10	2.0574+11	2.2990+11	2.1831+00
4.3084	1.7787-02	5.6220+01	2.4045+11	8.5923+10	6.7300+08	1.2547+11	2.9745+11	2.5355+11	2.6822+00
6.0318	9.8191-03	1.0184+02	4.5155+11	1.2025+11	6.3503+08	1.6890+11	5.5481+11	3.0373+11	3.6150+00
7.7551	6.2372-03	1.6033+02	7.5176+11	1.8175+11	7.9807+08	2.5334+11	9.1428+11	3.5590+11	4.5543+00
9.4785	4.2071-03	2.3769+02	1.1880+12	3.0260+11	1.0805+09	4.1803+11	1.4290+12	4.1533+11	5.6793+00

P = 1.0138+09 ($dynes/cm^2$) = 1.00+03 (atm)

TABLE 13

THERMODYNAMIC FUNCTIONS AT θ = 1.38 eV, Γ = 83

	$s_0 = 2$	$s_0 = 1$
Fractional populations		
p_0	0.365	0.351
p_1	0.537	0.541
p_2	0.098	0.108
ρ, g/cm^3	0.0633	0.612
P_{kin}, dynes/cm^2	6.21×10^{8}	6.09×10^{8}
P_p, dynes/cm^2	-1.17×10^{8}	-1.23×10^{8}
P, dynes/cm^2	5.04×10^{8}	4.89×10^{8}
E_{kin}, ergs/g	1.47×10^{10}	1.49×10^{10}
E_p, ergs/g	-5.56×10^{9}	-6.01×10^{9}
E_{ex}, ergs/g	2.06×10^{10}	2.14×10^{10}
E_{ion}, ergs/g	1.69×10^{10}	1.69×10^{10}
E, ergs/g	4.66×10^{10}	4.72×10^{10}
Γ	83	83
$\bar{z}$	0.734	0.758
C_v, ergs/g/eV	6.18×10^{10}	6.21×10^{10}
C_p, ergs/g/eV	7.31×10^{10}	7.32×10^{10}

Table 13 indicates that the thermodynamic properties are not very sensitive to the value of the parameter s_0 introduced in Appendix A. We have chosen a (T, Γ) point in whose vicinity thermodynamic functions are most sensitive to s_0. Thus, in view of Sec. 5.1 and Appendix A, the thermodynamic functions are not very sensitive to s_0 over the entire range of T, Γ considered here.

5. ELEMENTS OF OPACITY CALCULATION

Bound-bound, bound-free, and free-free processes make the dominant contributions to the spectral absorption coefficients in the uranium plasmas that we study. The scattering of photons plays a completely negligible role over the frequency range that is significant for the overall Planck and Rosseland mean opacities. The free-free absorption is significant only at very low frequencies ($h\nu \lesssim k_B T$) and we calculate it simply by means of Kramer's formula, (B-21), given in Appendix B. The calculation of bound-free and bound-bound absorption is a formidable problem requiring a detailed knowledge of the thermodynamic state of the gas and of the properties of electronic transition arrays contributing to the opacity. The most relevant of these properties are the strength of the array and its line statistics.

5. 1. TRANSITIONS AND STATE POPULATIONS

Much of the quantitative basis that is fundamental to the calculation of opacity has been established in the preceding sections. The populations of ionic quantum states follow from the statistical mechanical description of the plasma. We consider as contributing to the opacity the transitions by all electrons in initial subconfigurations defined by the general rules (a), (b), and (c) of Sec. 2. 2 and the shell classifications given in Table 6, provided the transition frequency ν lies in the range $0 \leq \nu \leq \nu_{max}$ that is significant for the overall Planck and Rosseland mean opacities. In particular, we consider only initial states having either zero or one E-electron.

Accordingly, corresponding to a transition in an ion A with charge k and having no E-electrons, there is a transition in an ion B that is obtained

by adding an E-electron to the A-ion. The number of A-ions in the subconfiguration K for each nucleus in the plasma is

$$f_k^{(A)} = p_k \frac{\phi_k(K)}{U_k} \quad , \tag{81}$$

where p_k is the fractional population of the ionic species k; $\phi_k(K)$ and U_k are defined in Sec. 3.2. The number of corresponding B-ions is given by

$$f_k^{(B)} = p_{k-1}\, h_{k-1} \frac{\phi_k(K)}{U_k^0} \quad , \tag{82}$$

where

$$h_k = \frac{U_k - U_k^0}{U_k} \tag{83}$$

is the fraction of ions of species k having an E-electron.

We are now in a position to give the number of initial states (referred to a single nucleus) that contribute in each of the possible transition types that we consider. If there is no E-electron present in the initial state and

(1) if an I-electron jumps to an E-shell or to an unbound state, then

$$f_k = p_k(1 - h_k) \quad , \tag{84}$$

where $1 - h_k$ is the probability that no E-electron is present initially;

(2) if the ion is initially in the subconfiguration K, and an I-electron jumps to an M-shell, or an M-electron jumps to an E-shell, to an M-shell, or to an unbound state, then

$$f_k = p_k \frac{\phi_k(K)}{U_k} \quad ; \tag{85}$$

(3) if an E-electron jumps to an E-shell or to an unbound state, then (see Eq. (74))

$$f_k = p_k h_k g_k(i)/U_k^E \quad . \tag{86}$$

If an E-electron is present in the initial state and

(4) an I-electron jumps to an E-shell or to an unbound state,

$$f_k = p_{k-1} h_{k-1} \quad ; \tag{87}$$

(5) if the M-shell electrons are initially in the subconfiguration K, and an I-electron jumps to an M-shell, or an M-electron jumps to an E-shell, to an M-shell, or to an unbound state, then

$$f_k = p_{k-1} h_{k-1} \frac{\phi_k(K)}{U_k^0} \quad . \tag{88}$$

5. 2. CROSS SECTION FOR BOUND-BOUND TRANSITIONS

The quantity of fundamental interest is the average cross section $\sigma_{ij}^{(Lin)}$ in an average line per state in the initial subconfiguration for a transition array in which an ion of the k^{th} species in an initial subconfiguration K absorbs a photon of frequency ω and makes a transition to a final subconfiguration K'. This cross section is given by

$$\sigma_{ij}^{(Lin)} = \frac{4\pi^2}{3} \alpha a_0^2 \hbar\omega M^2 \frac{w'}{\pi} \frac{1}{w'^2 + \hbar^2(\omega - \omega_0)^2} \quad , \tag{89}$$

where ω_0 is the line center, w' is the half-intensity half-width, and a_0 is the Bohr radius. The matrix element M is given by

$$M^2 = \frac{\kappa' r}{N_{Lin}} \quad , \tag{90}$$

where N_{Lin} is the number of lines in the transition array,

$$r = r_{ij} = \left| \int_0^\infty P_i(r)\, rP_j(r)\, dr \right|^2 = (4\ell_>^2 - 1)\, \sigma_{ij}^2 \quad . \tag{91}$$

P_i and P_j are the initial- and final-state wave functions of the jumping electron, and distances are measured in atomic units. The quantity κ' depends on the shells participating in the transition and their occupation numbers. Formulas for κ' are given in Table 14.

TABLE 14

FORMULAS FOR κ'

Shell		
Initial $\ell j(\ell)$	Final $\ell' j'(\ell')$	κ'
s 1/2	p 1/2	N/3[1 -(N'-1)/2]
s 1/2	p 3/2	2N/3[1 -(N'-1)/4]
p 1/2	s 1/2	N/3[1 -(N'-1)/2]
p 1/2	d	2N/3[1 -(N'-1)/10]
p 3/2	s 1/2	N/3[1 -(N'-1)/2]
p 3/2	d	2N/3[1 -(N'-1)/10]
d	p 1/2	2N/15[1 -(N'-1)/2]
d	p 3/2	4N/15[1 -(N'-1)/4]
d	f	3N/5[1 -(N'-1)/14]
f	d	3N/7[1 -(N'-1)/10]
f	g	4N/7[1 -(N'-1)/18]
g	f	4N/9[1 -(N'-1)/14]
g	h	5N/9[1 -(N'-1)/14]
$\ell>4$	ℓ'	1

Note: N = occupation number in $\ell j(\ell)$-shell before transition.
N' = occupation number in $\ell' j'(\ell')$-shell after transition.

The average value of the cross section in Eq. (89) over an energy interval $\delta(\hbar\omega) = \theta\,\delta(\hbar\omega)/\theta = \theta\Delta$ much greater than the line width w is

$$\bar{\sigma} = \bar{\sigma}_{ij} = \frac{4\pi^2}{3}\,\alpha\, a_0^2\,\frac{\hbar\omega}{\theta\Delta}\,M^2 \quad . \tag{92}$$

Later we shall require a quantity S, which is the product of $N_{Lin}\,\bar{\sigma}$ and the number of states $(N_0/A)\,f_k$ per gram of material contributing to the transition

$$S = \frac{N_0}{A}\,f_k\,\frac{4\pi^2}{3}\,\alpha\, a_0^2\,\frac{\hbar\omega}{\theta}\,\kappa' r \quad . \tag{93}$$

Here N_0/A is the number of uranium nuclei in one gram.

5. 3. CROSS SECTION FOR BOUND-FREE TRANSITIONS

The average photoelectric cross section per state in the initial sub-configuration K absorbing a photon with frequency $\hbar\omega$, the photoelectron emerging with kinetic energy $KE = k^2 Ry$, is

$$\sigma = \frac{4}{3}\,\alpha\pi a_0^2\left(\frac{\hbar\omega}{Ry}\right)\kappa' r(k) \quad , \tag{94}$$

where

$$r = r_{ij} = (4\ell_>^2 - 1)\frac{1}{k}\,\sigma_{ij}^2(k) \tag{95}$$

and

$$\sigma_{ij}^2(k) = \frac{1}{4\ell_>^2 - 1}\left[\int_0^\infty P_i(r)\; rP_j(k, r)\; dr\right]^2 \quad . \tag{96}$$

In Eq. (96) distances are again in atomic units and the wave function $P_j(k, r)$ of the photoelectron is normalized to unit amplitude at large distances

$$P_j(k, r) \xrightarrow[r\to\infty]{} \cos[kr + \delta(r)] \quad .$$

Later we shall require the quantity

$$S_c = \frac{N_0}{A} f_k \sigma \quad . \tag{97}$$

5. 4. LINE STATISTICS

The splitting of subconfigurations by electrostatic forces has a significant influence on the opacity. Instead of a single line, the totality of transitions (transition array) between a pair of subconfigurations yields in general a complicated spectrum consisting of many weaker lines. The important effect is to increase the Rosseland mean opacity. This effect can best be dealt with quantitatively in terms of band or cluster models.[17][18] In considering the line absorption, we take a cluster to be all lines in a transition array. Moreover, we take the line statistics of different arrays to be independent.

Stewart[19] has developed the theory of absorption by a line cluster that is most appropriate for our considerations. He considers the absorption of light by an array of N independent Lorentz lines of equal width and a mean strength S per line. All lines have a strength uncorrelated with the frequency of the line center, an identical Gaussian distribution of line centers

$$P(u_1 - u_0) = \pi^{-\frac{1}{2}} D^{-1} \exp\left[- \frac{(u_1 - u_0)^2}{D^2} \right] , \tag{98}$$

and an identical exponential strength distribution

$$Q(S_1) = S^{-1} \exp(-S_1/S) \quad . \tag{99}$$

Here u_1 is the frequency of a line center, u_0 is the most probable frequency, and D is the Gaussian width of the distribution, all in the dimensionless units of energy divided by $k_B T$.

5. 5. LOCAL PLANCK MEAN OPACITY

We denote the monochromatic bound-bound and bound-free mass absorption coefficients at frequency $\nu = k_B T\, u/h$ by $\kappa'_{bb}(u)$ and $\kappa'_{bf}(u)$, respectively. The local Planck mean opacity is defined by

$$\kappa_p(u) = \kappa_c(u) + \langle \kappa'_{bb}(u) \rangle \quad , \tag{100}$$

where

$$\kappa_c(u) = \kappa_{ff}(u) + \langle \kappa'_{bf}(u) \rangle \quad ; \tag{101}$$

$\kappa_{ff}(u)$ is the free-free absorption coefficient and the symbol $\langle \ldots \rangle$ means that a statistical expectation value is to be taken. If the lines are infinitely sharp, the contribution of the j^{th} cluster to the local Planck mean opacity $\kappa_p(u)$ is given by

$$\kappa_{p,\,j}(u) = \langle \kappa'_{bb,\,j}(u) \rangle$$

$$= S_j P_j(u - u_{0j}) \quad , \tag{102}$$

where u_{0j} is the mean transition frequency and S_j is the total strength of the array. The total line contribution to the $\kappa_p(u)$ follows on summing over all transition arrays.

To obtain the continuous absorption, we first consider the totality of transitions of an electron with quantum numbers $n\ell j$ (or $n\ell$) from an initial subconfiguration K. If we fix the kinetic energy, k^2Ry, and angular momentum of the ejected electron, but not the photon energy, we obtain a line spectrum whose total cross section is proportional to S_c of Eq. (97). We now want to determine the distribution of photon energies associated with the considered class of transitions. This must be essentially the same distribution that would apply in the case of a bound-bound transition array where the jumping electron in its final quantum state does not interact with the parent subconfiguration [K] of electrons not participating in the transition.

Since the distribution of photon energies for a bound-bound transition array is Gaussian, the statistical model that we have assumed dictates that the continuous absorption from the group of photoionizing transitions

$$K'n\ell j \rightarrow K'k\ell'j'$$

and having k in the interval dk proportional to

$$S_c(n\ell j, k\ell'j')\, P(u - u_0)\, du_0 \quad , \tag{103}$$

where $u_0\theta = k^2 Ry - \epsilon_{n\ell j}(\kappa)$ is the mean transition energy and S_c is the total cross section of the "transition array." The total continuous absorption at u associated with the transition of an electron in a specified shell in some initial subconfiguration is obtained by summing the contribution from all possible values of the continuous variable k^2. If $S_c(n\ell j,\ k\ell'j')$ does not vary appreciably over a cluster width D and the frequency u is greater than $-\epsilon_{n\ell j}/\theta$ by several cluster widths, then

$$\langle \kappa'_{bf}(u) \rangle = S_c \int_{-\epsilon_{n\ell j}/\theta}^{\infty} P(u - u_0)\, du_0 \approx S_c \quad . \tag{104}$$

In other cases, the summation over k should be carried out explicitly. One consequence of this summation is that the set of absorption edges which in the most precise calculation would originate from the $K'n\ell j \rightarrow K'k\ell'j'$ transitions are replaced by an edge profile having a smooth variation over a frequency range $\Delta u \sim D$.

5.6. TRANSMISSION--LOCAL ROSSELAND MEAN OPACITY

To determine the local Rosseland mean opacity, Stewart[19] first considers the statistical expectation of the transmission of white light through a slab of mass depth m in the presence of a single line cluster. The transmission in the presence of the cluster j of N lines is

$$T'_j(m, u) = \exp[-m\kappa'_{bb,\,j}(u)] \tag{105}$$

a ıd its expectation value is

$$T_j(m, u) = \langle T_j^!(m, u) \rangle \quad . \tag{106}$$

For the cluster model defined by Eqs. (98) and (99)

$$T_j(m, u) = [1 - \bar{\tau}\overline{H}(a, x)]^N \quad , \tag{107}$$

where

$$\bar{\tau} = \frac{wmS}{\pi^{\frac{1}{2}} D^2} \frac{H(a, 0)}{Na} \quad , \tag{108}$$

Θw is the half-intensity half-width in energy units,

$$x = (u - u_0)/D \quad , \tag{109}$$

$$a = D^{-1} \left(w^2 + \frac{mwS}{N\pi} \right)^{\frac{1}{2}} \quad , \tag{110}$$

$$\overline{H}(a, x) = H(a, x)/H(a, 0) \quad , \tag{111}$$

and

$$H(a, x) = \frac{a}{\pi} \int_{-\infty}^{\infty} \frac{e^{-y^2}}{(x - y)^2 + a^2} \tag{112}$$

is the Voigt function.[20]

We obtain the local Rosseland mean opacity from

$$\frac{1}{\kappa_R(u)} = \int_0^{\infty} \exp[-m\kappa_c(u)] \prod_j T_j(m, u)\, dm \tag{113}$$

where $\prod_j T_j$ is the product of transmissions of all line clusters and we have assumed that clusters are statistically independent. We have also assumed that the transmission $T_c(m, u)$ in the case of continuous absorption is given by

$$T_c(m, u) = \exp[-m\kappa_c(u)] \quad , \tag{114}$$

i. e., we have made the approximation

$$\left\langle \exp[-m\kappa'_{bf}(u)] \right\rangle = \exp[-m\langle \kappa'_{b,f}(u) \rangle] \quad , \tag{115}$$

where $\kappa_c(u)$ is given by Eq. (101).

The transmission by a cluster follows once we know the mean transition energy, the number of lines in a cluster, the cluster width, the strength of a cluster, and the line width. For a more detailed description of the method of calculating the transmission by a cluster, see Appendix C. We already have the strength and the mean transmission energy

$$u_0 = [\epsilon_j(K_f) - \epsilon_{j'}(K_i)]/\Theta \quad . \tag{116}$$

Here, K_f and K_i are the initial and final subconfigurations, respectively, and j and j' represent the set of initial and final quantum numbers, respectively, of the jumping electron.

5. 7. NUMBER OF LINES IN A CLUSTER

The number of lines in a transition array depends strongly on what are good quantum numbers of the atomic system. In atomic systems, configurations having LS terms lead to fewer lines than configurations where the terms are split into levels corresponding to states with a given total angular momentum J.

We suppose first of all that we know the number of lines in the array K'i → K'i', where the parent configuration K' contains electrons, possibly in incomplete shells, none of which are equivalent to the jumping electron in either the initial or final state. Now we consider the case where i is an occupied shell of K' but i' is not; that is, the jumping electron is an equivalent electron in the initial subconfiguration. The following conjecture leads to a quantitative and apparently accurate basis for estimating the number of lines in the array K'i → K'i'. The conjecture is that the ratio of the number of levels in Ki to the number of lines coming from the transition i → i' is

given to a good approximation by treating the jumping electrons as nonequivalent in the initial subconfiguration. To express this conjecture quantitatively and perhaps somewhat more clearly, we let $N_{Lev}(\ldots N_i + 1 \ldots)$ denote the number of levels in the initial subconfiguration having $N_i + 1$ equivalent electrons in the i^{th} shell and distinguish it from $N_{Lev}(\ldots (N_i, 1) \ldots)$, the number of levels that would pertain in the case that we treat as nonequivalent the single electron added to the N_i electrons already in the i^{th} shell. Similarly, we distinguish in these two cases the number of lines

$$N_{Lin}(\ldots (N_i + 1),\ N_{i'} = 0 \rightarrow \ldots N_i, N_{i'} = 1)$$

and

$$N_{Lin}(\ldots (N_i, 1),\ N_{i'} = 0 \rightarrow \ldots N_i, N_{i'} = 1)$$

for the transition $i \rightarrow i'$ of an electron from the shell i in an initial subconfiguration in which the shell i' is initially unoccupied. The $(\ldots)$ represent occupation numbers of nonparticipating shells. Our conjecture then is

$$\frac{N_{Lin}(\ldots N_i + 1,\ N_{i'} = 0 \rightarrow \ldots N_i, N_{i'} = 1)}{N_{Lin}(\ldots (N_i, 1),\ N_{i'} = 0 \rightarrow \ldots N_i, N_{i'} = 1)} \approx \frac{N_{Lev}(\ldots N_i + 1, N_{i'} = 0)}{N_{Lev}(\ldots (N_i, 1))} \quad . \quad (117)$$

The level number can be calculated by the method described in Sec. 2. 3. 2. To estimate the number of lines when the jumping electron is nonequivalent in the final state, we have only to estimate the number of lines that obtain when this electron is treated as nonequivalent also in the initial subconfiguration.

It is simple to generalize Eq. (117) so that it applies when the jumping electron may be equivalent in the final as well as in the initial subconfiguration. Owing to the symmetry with respect to exchange of initial and final states, we may write

$$N_{Lin}(\ldots N_i + 1, N_{i'} \rightarrow \ldots N_i, N_{i'} + 1) \approx$$

$$N_{Lin}(\ldots (N_i, 1), N_{i'} \rightarrow \ldots N_i, (N_{i'}, 1) \frac{N_{Lev}(\ldots N_i + 1, N_i)}{N_{Lev}(\ldots (N_i, 1), N_{i'})} \frac{N_{Lev}(\ldots N_i, N_{i'} + 1)}{N_{Lev}(\ldots N_i, (N_{i'}, 1))} . \quad (118)$$

In Table 15 we test the above estimate by comparing it with the actual number of lines (multiplets) when the states in initial and final configurations are described in an LSJ (LS) coupling scheme. In the case of multiplets, N_{Lin} is interpreted as the number of multiplets and N_{Lev} as the number of terms. The estimated values are given to the nearest integer. Except for the number of lines in the $p^2 \rightarrow pd$ array, Eq. (118) approximates the actual number of lines (multiplets) to within about 10 percent.

TABLE 15

NUMBER OF LINES (MULTIPLETS) IN A TRANSITION ARRAY

Transition Array	Number of Lines		Number of Multiplets	
	Estimated	Actual	Estimated	Actual
$f^2 \rightarrow fd$	53	54	16	16
$p^2 \rightarrow pd$	12	16	6	6
$d^2 \rightarrow dp$	32	30	9	9
$d^3 \rightarrow d^2p$	192	203	46	50
$d^3p \rightarrow d^2p^2$	287	317	71	79

To complete our calculation we require an estimate of the number of lines in the case that the jumping electron is considered nonequivalent both before and after the transition. We focus on particular angular momentum states formed by coupling the angular momentum of the jumping electron to the core angular momentum J of the remaining electrons. We ask for the number of lines in the array $\ell j \rightarrow \ell' j'$, with the selection rule that the core

momentum does not change. It is difficult to establish a general rule for the number of lines $n_{Lin}(J, j')$ in this array, but the following is a reasonable estimate:

$$n_{Lin}(J, j, j') = 6J + 1 \qquad J < \min(j, j')$$

$$n_{Lin}(J, j, j') = 6 \min(j, j') + 1 \qquad J > \min(j, j') + 1$$

$$n_{Lin}(J, j, j') = 6 \min(j, j') + 2 \qquad \min(j, j') \leq J \leq \min(j, j') + 1 \ .$$

For the quantity N_{Lin} on the right-hand side of Eq. (118), we then obtain

$$N_{Lin}(\ldots(N_{n\ell j}, 1), N_{n'\ell'j'} \rightarrow \ldots N_{n\ell j}, (N_{n'\ell'j'}, 1))$$

$$= N_{Lev}(K) \int_0^\infty n_{Lin}(J, j, j') f_K(J)\, dJ$$

$$= N_{Lev}(K) \left\{ \exp(-\beta_K v^2) - \exp\left[-\beta_K (v+1)^2\right] + \frac{6\sqrt{\pi}}{2\beta_K^{\frac{1}{2}}} \operatorname{erf}\left(\beta_K^{\frac{1}{2}} v\right) \right\} \ , \quad (120)$$

where $f_K(J)$ is the angular momentum distribution function for the subconfiguration $K = (\ldots N_{n\ell j}, N_{n'\ell'j'})$,

$$v = \min(j, j') \ , \quad (121)$$

$$\beta_K = \frac{4}{\pi}[J_{av}(K)]^2 \ , \quad (122)$$

and J_{av} is given by Eq. (40).

5. 8. CLUSTER WIDTH

Moszkowski et al. have given a general formula for the variance of multiplet distributions in terms of the variance of two-electron multiplets.[21] We may express their result in the form

$$\Delta^2 E(N_i, N_j - 1, \{N_k\} \ldots \rightarrow N_i - 1, N_j, \{N_k\})$$

$$= \frac{(N_i - 1)(M_i - N_i)}{M_i - 2} \Delta^2 E(i^2 \rightarrow ij) + \frac{(N_j - 1)(M_j - N_j)}{M_j - 2} \Delta^2 E(ij \rightarrow j^2)$$

$$+ \sum_{k \neq i, j} \frac{N_k(M_k - N_k)}{M_k - 1} \Delta^2 E(ik \rightarrow jk) \quad , \quad (123)$$

where M_k is the degeneracy of the shell k and the sum goes over all shells $k \neq i$, $k \neq j$ containing electrons that do not participate in the transition. The quantities $\Delta^2 E(ik \rightarrow jk)$ are the variances of the multiplet distribution generated by the transition $i \rightarrow j$ from an initial configuration containing two nonequivalent electrons, one in shell i and the other in shell k. Similarly, $\Delta^2 E(i^2 \rightarrow ij)$ and $\Delta^2 E(ij \rightarrow j^2)$ are variances of two-electron multiplet distributions where the jumping electron is equivalent in the initial and final configurations, respectively. The proof of Eq. (123) rests on the approximation that the jumping electron in the final state j does not interact with the electron in i. From this approximation,

$$\Delta^2 E(ik \rightarrow jk) = \Delta^2 E(ik) \quad , \quad (124)$$

i. e., the two-electron multiplet and term variances are equal.

In uranium this approximation of noninteraction is a poor one for many transition arrays. Nevertheless, we apply Eqs. (123) and (124) to the determination of cluster widths in uranium, where now the sum in Eq. (123) goes over the occupied $n\ell j$ and $n\ell$ shells. The $\Delta^2 E(ik)$ are given in Table 16 for the case where both i and k refer to shells of type M. When at least one of the shells is not of type M, we use an estimate given by Stewart[22]

$$\Delta^2 E(ik) = \frac{z'}{10} n_<^* / (n_>^*)^3 \quad , \quad (125)$$

where $n_<^*(n_>^*)$ is the lesser (greater) of $n^*(i)$ and $n^*(k)$.

TABLE 16

ENERGY LEVEL VARIANCES FOR TWO ELECTRONS OUTSIDE CLOSED SHELLS (Ry^2)

i	j	z' = 1	z' = 2	z' = 3	z' = 4
7s,	7s	0	0	0	0
	6d	1.9259×10^{-3}	1.7069×10^{-3}	1.8074×10^{-3}	2.0541×10^{-3}
	5f	3.6865×10^{-5}	2.9437×10^{-5}	4.4025×10^{-5}	4.9643×10^{-5}
6d,	6d	2.3209×10^{-3}	2.8942×10^{-3}	3.2217×10^{-3}	3.3724×10^{-3}
	5f	2.6746×10^{-3}	3.0554×10^{-3}	4.1645×10^{-3}	3.9120×10^{-3}
5f,	5f	8.8224×10^{-3}	9.6502×10^{-3}	8.6767×10^{-3}	8.8982×10^{-3}
i	j	z' = 5	z' = 6	z' = 7	z' = 8
6p1/2,	6p1/2	1.3729×10^{-2}	1.4109×10^{-2}	1.4589×10^{-2}	1.4905×10^{-2}
	6p3/2	1.1537×10^{-2}	1.2006×10^{-2}	1.2494×10^{-2}	1.2854×10^{-2}
	6d	1.9108×10^{-2}	2.1969×10^{-2}	2.4837×10^{-2}	2.7061×10^{-2}
	5f	3.2798×10^{-2}	3.2515×10^{-2}	3.0105×10^{-2}	3.1837×10^{-2}
6p3/2,	6p3/2	1.0711×10^{-2}	1.1191×10^{-2}	1.1684×10^{-2}	1.2061×10^{-2}
	6d	2.6865×10^{-2}	3.0181×10^{-2}	3.3499×10^{-2}	3.6006×10^{-2}
	5f	1.9156×10^{-2}	1.8791×10^{-2}	1.6825×10^{-2}	1.8162×10^{-2}
6d,	6d	3.9631×10^{-3}	4.4411×10^{-3}	4.9124×10^{-3}	5.2856×10^{-3}
	5f	4.8651×10^{-3}	5.0251×10^{-3}	4.5970×10^{-3}	5.3212×10^{-3}
5f,	5f	9.1853×10^{-3}	9.9827×10^{-3}	1.1425×10^{-2}	1.1294×10^{-2}
i	j	z' = 9	z' = 10	z' = 11	z' = 12
6p1/2,	6p1/2	1.5261×10^{-2}	1.4971×10^{-2}	1.5423×10^{-2}	1.5894×10^{-2}
	6p3/2	1.3252×10^{-2}	1.3096×10^{-2}	1.3570×10^{-2}	1.4054×10^{-2}
	5f	3.0361×10^{-2}	2.9358×10^{-2}	3.0147×10^{-2}	3.0632×10^{-2}
6p3/2,	6p3/2	1.2469×10^{-2}	1.2361×10^{-2}	1.2834×10^{-2}	1.3314×10^{-2}
	5f	1.7147×10^{-2}	1.6696×10^{-2}	1.7301×10^{-2}	1.7686×10^{-2}
5f,	5f	1.2150×10^{-2}	1.2005×10^{-2}	1.2297×10^{-2}	1.2691×10^{-2}

5. 9. LINE WIDTH

In the range of pressures and temperatures that we consider the principal contribution to line broadening came from electron collisions. The electron half-width at half-intensity is approximated[23] by

$$w'_e = \frac{2}{\Gamma} \frac{n'^4_*}{z^2} \Theta , \tag{126}$$

where n'_* is the effective principal quantum number of the jumping electron in the final state. The result is intended to apply only to lines with upper states that are Rydberg states, but we apply it to all lines.

Natural broadening has a relatively insignificant effect on the line width. We include a rough estimate of the natural width w_n only as a provision in the case that it is attempted to apply the computer program to the calculation of the Rosseland opacity in a low-pressure region where the collision width becomes small. We use a hydrogenic approximation and take account only of spontaneous decays to a state whose effective principal quantum number is determined by the ionization potential of the ion;

$$w_n = \frac{16}{3\sqrt{3}} \alpha^3 \left[I_k - z'^2 \, Ry / n_*^2 \right]^{-1} \left(\frac{k+1}{n_*} \right)^3 \left(\frac{I_k}{Ry} \right)^{\frac{3}{2}} \frac{Ry^2}{n^2} . \tag{127}$$

Here n_* is the effective principal quantum number of the excited electron. The relation of n_* to the binding energy of the excited level is given by Eq. (1).

6. THE CALCULATED OPACITY

6.1. DISCUSSION OF RESULTS

We have calculated the local and overall Planck and Rosseland mean opacities (see Appendix D) at the same temperatures and pressures as were used in the calculation of thermodynamic properties and composition. In Appendix E, we give a detailed description of the computer program used to carry out the calculations in this report. The opacity results are listed in Table 17 and shown in Figs. 3 and 4 using properties of one-electron wave functions described in Sec. 2.1. The tabulations give the local continuous opacity and the local Planck and Rosseland means, including both line and bound-free transitions. The u in Table 17 is the value of u at the end of the frequency interval. The line contribution is dominant in all cases. At 5000°K, the line contribution to the Rosseland mean is more than one thousand times greater than the contribution from the continuous opacity. The ratio of overall Planck and Rosseland means is never much greater than one, indicating that the line spectrum is not very gappy. The gappiness tends to increase at the higher temperatures, where ions with only one or two incomplete shells of electrons are predominant and the transition arrays consist of a much smaller number of lines than are present when neutral uranium exists in significant proportions.

Although there is no simple way to ascertain the accuracy of the results listed in Table 17, we have examined their sensitivity to changes in the number of ions and of subconfigurations that are included as initial states of transitions. We find that the opacity is essentially the same for cases (1) and (2) below:

(1) We neglect all ions having $p_k < 0.005$ and M-shell subconfigutions K in each ion having $\Phi_k(K)/U_k < 0.005$.

(2) We neglect all ions having $p_k < 0.001$ and M-shell subconfigurations K in each ion having $\Phi_k(K)/U_k < 0.001$.

TABLE 17

LOCAL AND OVERALL CONTINUOUS PLANCK AND ROSSELAND MEAN OPACITIES

THETA= 4.3946-01 EV = 9.1660+03 DEG R = 5.1000+03 DEG K

GAMMA= 8.9900+06

PRESSURE= 3.6317+02 (DYNE/CM2) = 3.5843-04 (ATM)

RHO= 1.2445-07 (G/CM3) = 7.7694-06 (LB/FT3)

ZBAR= 6.1956-01

UMAX	DELTA U
28.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	1.7102+01	2.5825+03	9.6901+01
1.00	3.4103+00	3.1453+03	6.0243+01
1.50	1.7102+00	3.6589+03	7.0777+01
2.00	1.3626+00	4.1506+03	7.4785+01
2.50	1.3260+00	4.6190+03	7.9591+01
3.00	2.1366+00	5.0448+03	9.3626+01
3.50	3.5173+00	5.3936+03	1.1269+02
4.00	5.2896+00	5.7545+03	1.3681+02
4.50	8.5647+00	6.0822+03	1.6905+02
5.00	1.4481+01	6.4494+03	2.1958+02
5.50	2.4552+01	7.0340+03	2.9455+02
6.00	4.1379+01	8.0940+03	4.0368+02
6.50	6.8766+01	1.0096+04	5.6262+02
7.00	1.1192+02	1.3596+04	7.8531+02
7.50	1.7748+02	1.9216+04	1.0850+03
8.00	2.7314+02	2.6366+04	1.4591+03
8.50	4.0704+02	3.4894+04	1.9016+03
9.00	5.8675+02	4.5816+04	2.4316+03
9.50	8.1851+02	1.3762+05	3.6912+03
10.00	1.1060+03	3.7884+05	5.7670+03
10.50	1.4510+03	1.5828+05	5.0462+03
11.00	1.8516+03	8.5759+04	4.8553+03
11.50	2.3011+03	9.0974+04	5.3578+03
12.00	2.7858+03	9.3469+04	5.7784+03
12.50	3.2851+03	2.8277+05	7.1674+03
13.00	3.7921+03	8.2197+05	9.4431+03
13.50	4.2575+03	2.5252+05	7.2719+03
14.00	4.9012+03	4.1243+04	6.3557+03
14.50	5.5444+03	2.6848+04	6.6707+03
15.00	6.1444+03	1.9935+04	7.1685+03
15.50	6.6652+03	1.7014+04	7.7542+03
16.00	7.0311+03	1.6636+04	8.4416+03
16.50	7.3627+03	1.7719+04	9.3502+03
17.00	7.6673+03	1.9236+04	1.0481+04
17.50	7.9626+03	2.0721+04	1.1770+04
18.00	8.2816+03	2.1675+04	1.3099+04
18.50	8.6715+03	2.1878+04	1.4346+04
19.00	9.1877+03	2.1443+04	1.5423+04
19.50	9.8751+03	2.0664+04	1.6176+04
20.00	1.0754+04	1.9705+04	1.6646+04
20.50	1.1802+04	1.8775+04	1.6856+04
21.00	1.2927+04	1.8117+04	1.6924+04
21.50	1.4050+04	1.9338+04	1.7134+04
22.00	1.4366+04	2.3354+04	1.6766+04
22.50	1.4420+04	1.7726+04	1.5868+04
23.00	1.4264+04	1.6259+04	1.5272+04
23.50	1.3971+04	1.8576+04	1.4974+04
24.00	1.3613+04	2.9761+04	1.5059+04
24.50	1.3241+04	6.9155+04	1.5806+04
25.00	1.2883+04	2.7911+04	1.4012+04
25.50	1.2550+04	1.3043+04	1.2826+04
26.00	1.2229+04	1.2475+04	1.2459+04
26.50	1.1933+04	1.2632+04	1.2321+04
27.00	1.1663+04	1.6081+04	1.2710+04
27.50	1.1408+04	2.1665+04	1.2877+04
28.00	1.1167+04	1.3884+04	1.1748+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
5.3140+01	9.5718+03	3.9461+00	1.3969+02

2.3337-13	2.5459-03	10508	745	673	72

TABLE 17 (sheet 2 of 57)

THETA= 4.3084-01 EV = 8.9862+03 DEG R = 5.0000+03 DEG K

GAMMA= 7.6700+03

PRESSURE= 1.0148+08 (DYNE/CM2) = 1.0015+02 (ATM)

RHO= 5.7268-02 (G/CM3) = 3.5752+00 (LB/FT3)

ZBAR= 1.5319-03

UMAX	DELTA U
27.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	3.2397+01	6.6359+03	4.4998+03
1.00	5.8764+00	7.8431+03	5.5093+03
1.50	3.2008+00	9.1424+03	6.6483+03
2.00	2.6865+00	1.0386+04	7.7005+03
2.50	2.4802+00	1.1542+04	8.6682+03
3.00	3.7337+00	1.2590+04	9.4791+03
3.50	6.8288+00	1.3397+04	1.0076+04
4.00	1.0006+01	1.3904+04	1.0453+04
4.50	1.6277+01	1.4375+04	1.0499+04
5.00	2.7031+01	1.4037+04	1.0460+04
5.50	4.5467+01	1.4899+04	1.0372+04
6.00	7.6515+01	1.5633+04	1.0489+04
6.50	1.2758+02	1.7632+04	1.1310+04
7.00	2.0927+02	2.2158+04	1.3569+04
7.50	3.3579+02	3.0687+04	1.8507+04
8.00	5.2466+02	4.4939+04	2.7631+04
8.50	7.9576+02	6.3195+04	4.2026+04
9.00	1.1694+03	8.5230+04	6.0796+04
9.50	1.6643+03	1.1014+05	8.2141+04
10.00	2.2946+03	1.3538+05	1.0526+05
10.50	3.0706+03	1.6198+05	1.2743+05
11.00	3.9953+03	1.8684+05	1.5033+05
11.50	5.0627+03	2.0981+05	1.7070+05
12.00	6.2547+03	2.2549+05	1.8336+05
12.50	7.5340+03	2.2337+05	1.8365+05
13.00	8.6494+03	2.0479+05	1.6395+05
13.50	1.0184+04	1.6920+05	1.3253+05
14.00	1.1469+04	1.2834+05	9.5279+04
14.50	1.3181+04	9.1494+04	6.5937+04
15.00	1.4890+04	6.2811+04	4.6285+04
15.50	1.6481+04	4.5528+04	3.6986+04
16.00	1.7921+04	3.8902+04	3.4981+04
16.50	1.8893+04	3.9092+04	3.7283+04
17.00	1.9772+04	4.3053+04	4.1934+04
17.50	2.0575+04	4.7684+04	4.7020+04
18.00	2.1391+04	5.1727+04	5.1284+04
18.50	2.2253+04	5.4145+04	5.3336+04
19.00	2.3305+04	5.4323+04	5.3713+04
19.50	2.4687+04	5.3154+04	5.2751+04
20.00	2.6509+04	5.1318+04	5.1045+04
20.50	2.8617+04	4.9238+04	4.9145+04
21.00	3.1550+04	4.7338+04	4.7297+04
21.50	3.4474+04	4.6085+04	4.6063+04
22.00	3.7393+04	4.4923+04	4.4917+04
22.50	3.6535+04	4.3484+04	4.3481+04
23.00	3.8652+04	4.1678+04	4.1675+04
23.50	3.8223+04	3.9868+04	3.9867+04
24.00	3.7426+04	3.8373+04	3.8368+04
24.50	3.6448+04	3.7115+04	3.7094+04
25.00	3.5420+04	3.5955+04	3.5934+04
25.50	3.4404+04	3.4875+04	3.4854+04
26.00	3.3489+04	3.3922+04	3.3899+04
26.50	3.2598+04	3.3000+04	3.2977+04
27.00	3.1778+04	3.2147+04	3.2125+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.0420+02	1.6102+04	7.3834+00	9.8394+03

1.7043-06 3.7698-03 3054 81 81 30

TABLE 17 (sheet 3 of 57)

THETA= 4.3084-01 EV = 8.9862+03 DEG R = 5.0000+03 DEG K

GAMMA= 5.2500+03

PRESSURE= 2.0309+08 (DYNE/CM2) = 2.0043+02 (ATM)

RHO= 1.1465-01 (G/CM3) = 7.1577+00 (LB/FT3)

ZBAR= 1.1179-03

UMAX	DELTA U
27.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	3.4529+01	6.6410+03	4.8116+03
1.00	6.1436+00	7.8468+03	5.8465+03
1.50	3.2806+00	9.1465+03	6.9574+03
2.00	2.7208+00	1.0391+04	8.0980+03
2.50	2.4983+00	1.1547+04	9.0978+03
3.00	3.7451+00	1.2596+04	9.9448+03
3.50	6.8380+00	1.3403+04	1.0572+04
4.00	1.0015+01	1.3910+04	1.0978+04
4.50	1.6287+01	1.4381+04	1.1032+04
5.00	2.7045+01	1.4644+04	1.1026+04
5.50	4.5489+01	1.4905+04	1.1026+04
6.00	7.6550+01	1.5640+04	1.1239+04
6.50	1.2764+02	1.7640+04	1.2268+04
7.00	2.0937+02	2.2168+04	1.4960+04
7.50	3.3594+02	3.0700+04	2.0704+04
8.00	5.2490+02	4.4959+04	3.1064+04
8.50	7.9611+02	6.3223+04	4.6747+04
9.00	1.1699+03	8.5268+04	6.6764+04
9.50	1.6651+03	1.1019+05	8.9403+04
10.00	2.2956+03	1.3544+05	1.1302+05
10.50	3.0720+03	1.6206+05	1.3605+05
11.00	3.9970+03	1.8692+05	1.5971+05
11.50	5.0649+03	2.0990+05	1.8118+05
12.00	6.2575+03	2.2559+05	1.9340+05
12.50	7.5374+03	2.2347+05	1.9400+05
13.00	8.8533+03	2.0488+05	1.7452+05
13.50	1.0189+04	1.6927+05	1.4174+05
14.00	1.1474+04	1.2840+05	1.0429+05
14.50	1.2187+04	9.1534+04	7.1636+04
15.00	1.4897+04	6.2839+04	4.9680+04
15.50	1.6489+04	4.5548+04	3.8647+04
16.00	1.7928+04	3.8919+04	3.5839+04
16.50	1.8901+04	3.9110+04	3.7688+04
17.00	1.9781+04	4.3072+04	4.2102+04
17.50	2.0584+04	4.7706+04	4.7060+04
18.00	2.1400+04	5.1750+04	5.1254+04
18.50	2.2262+04	5.4169+04	5.3283+04
19.00	2.3316+04	5.4348+04	5.3662+04
19.50	2.4698+04	5.3178+04	5.2728+04
20.00	2.6521+04	5.1341+04	5.1039+04
20.50	2.8830+04	4.9260+04	4.9179+04
21.00	3.1564+04	4.7360+04	4.7318+04
21.50	3.4[illegible]+04	4.6106+04	4.6084+04
22.00	3.7410+04	4.[illegible]943+04	4.4937+04
22.50	3.0852+04	4.3504+04	4.3500+04
23.00	3.8669+04	4.1697+04	4.1695+04
23.50	3.8240+04	3.9886+04	3.9886+04
24.00	3.7442+04	3.8390+04	3.8386+04
24.50	3.6462+04	3.7131+04	3.7112+04
25.00	3.5435+04	3.5971+04	3.5951+04
25.50	3.4419+04	3.4891+04	3.4871+04
26.00	3.3504+04	3.3937+04	3.3916+04
26.50	3.2612+04	3.3014+04	3.2993+04
27.00	3.1789+04	3.2161+04	3.2140+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.0929+02	1.6110+04	7.6508+00	1.8417+04

1.6925-06 3.6468-03 3054 81 82 29

TABLE 17 (sheet 4 of 57)

THETA= 4.3084-01 EV = 8.9862+03 DEG R = 5.0000+03 DEG K

GAMMA= 3.1650+03

PRESSURE= 5.0521+08 (DYNE/CM2) = 4.9860+02 (ATM)

RHO= 2.8531-01 (G/CM3) = 1.7812+01 (LB/FT3)

ZBAR= 7.4516-04

UMAX	DELTA U
27.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	3.8162+01	6.6472+03	5.1676+03
1.00	6.5985+00	7.8504+03	6.2300+03
1.50	3.4160+00	9.1503+03	7.3771+03
2.00	2.7785+00	1.0395+04	8.5582+03
2.50	2.5282+00	1.1552+04	9.6077+03
3.00	3.7634+00	1.2601+04	1.0503+04
3.50	6.8513+00	1.3409+04	1.1174+04
4.00	1.0026+01	1.3916+04	1.1511+04
4.50	1.6299+01	1.4387+04	1.1739+04
5.00	2.7060+01	1.4650+04	1.1781+04
5.50	4.5510+01	1.4911+04	1.1807+04
6.00	7.6583+01	1.5646+04	1.2205+04
6.50	1.2769+02	1.7647+04	1.3522+04
7.00	2.0945+02	2.2177+04	1.6788+04
7.50	3.3607+02	3.0713+04	2.3427+04
8.00	5.2511+02	4.4977+04	3.5174+04
8.50	7.9643+02	6.3249+04	5.2066+04
9.00	1.1704+03	8.5302+04	7.2972+04
9.50	1.6657+03	1.1023+05	9.6247+04
10.00	2.2965+03	1.3549+05	1.2059+05
10.50	3.0732+03	1.6212+05	1.4410+05
11.00	3.9986+03	1.8699+05	1.6846+05
11.50	5.0670+03	2.0991+05	1.9038+05
12.00	6.2600+03	2.2568+05	2.0259+05
12.50	7.5404+03	2.2356+05	2.0317+05
13.00	8.8569+03	2.0497+05	1.8389+05
13.50	1.0193+04	1.6934+05	1.5099+05
14.00	1.1479+04	1.2845+05	1.1221+05
14.50	1.3193+04	9.1571+04	7.7984+04
15.00	1.4903+04	6.2864+04	5.3660+04
15.50	1.6495+04	4.5566+04	4.0889+04
16.00	1.7936+04	3.8935+04	3.6949+04
16.50	1.8909+04	3.9126+04	3.8177+04
17.00	1.9789+04	4.3089+04	4.2252+04
17.50	2.0592+04	4.7725+04	4.7017+04
18.00	2.1409+04	5.1771+04	5.1070+04
18.50	2.2271+04	5.4190+04	5.3059+04
19.00	2.3325+04	5.4369+04	5.3451+04
19.50	2.4708+04	5.3199+04	5.2585+04
20.00	2.6531+04	5.1362+04	5.0938+04
20.50	2.8842+04	4.9280+04	4.9168+04
21.00	3.1577+04	4.7378+04	4.7337+04
21.50	3.4503+04	4.6124+04	4.6103+04
22.00	3.7425+04	4.4961+04	4.4955+04
22.50	3.8568+04	4.3521+04	4.3518+04
23.00	3.8685+04	4.1713+04	4.1712+04
23.50	3.8255+04	3.9902+04	3.9902+04
24.00	3.7457+04	3.8405+04	3.8404+04
24.50	3.6476+04	3.7146+04	3.7143+04
25.00	3.5449+04	3.5986+04	3.5967+04
25.50	3.4433+04	3.4905+04	3.4886+04
26.00	3.3517+04	3.3950+04	3.3932+04
26.50	3.2625+04	3.3027+04	3.3009+04
27.00	3.1802+04	3.2174+04	3.2155+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.0940+02	1.6116+04	7.5601+00	1.1117+04

1.6335-06	3.5155-03	3054	81	53	28

TABLE 17 (sheet 5 of 57)

THETA= 4.3084-01 EV = 8.9862+03 DEG R = 5.0000+03 DEG K

GAMMA= 2.1300+03

PRESSURE= 1.0167+09 (DYNE/CM2) = 1.0034+03 (ATM)

RHO= 5.7429-01 (G/CM3) = 3.5853+01 (LB/FT3)

ZBAR= 5.5008-04

UMAX	DELTA U
27.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	4.1845+01	6.6522+03	5.4201+03
1.00	6.9422+00	7.8523+03	6.4834+03
1.50	3.4251+00	9.1521+03	7.6564+03
2.00	2.8364+00	1.0398+04	8.8188+03
2.50	2.5581+00	1.1555+04	9.9735+03
3.00	3.6409+00	1.2604+04	1.0808+04
3.50	6.8026+00	1.3413+04	1.1607+04
4.00	9.8060+00	1.3921+04	1.1998+04
4.50	1.5906+01	1.4393+04	1.2208+04
5.00	2.6372+01	1.4652+04	1.2332+04
5.50	4.4320+01	1.4913+04	1.2420+04
6.00	7.4553+01	1.5647+04	1.2925+04
6.50	1.2770+02	1.7651+04	1.4464+04
7.00	2.0949+02	2.2182+04	1.8131+04
7.50	3.3614+02	3.0719+04	2.5377+04
8.00	5.2521+02	4.4986+04	3.7703+04
8.50	7.9659+02	6.3261+04	5.5133+04
9.00	1.1706+03	8.5319+04	7.6348+04
9.50	1.6661+03	1.1025+05	9.9897+04
10.00	2.2970+03	1.3552+05	1.2491+05
10.50	3.0738+03	1.6215+05	1.4865+05
11.00	3.9994+03	1.8703+05	1.7263+05
11.50	5.0680+03	2.1003+05	1.9443+05
12.00	6.2612+03	2.2572+05	2.0772+05
12.50	7.5419+03	2.2361+05	2.0830+05
13.00	8.8586+03	2.0501+05	1.8817+05
13.50	1.0195+04	1.6937+05	1.5549+05
14.00	1.1481+04	1.2848+05	1.1682+05
14.50	1.3195+04	9.1593+04	8.1615+04
15.00	1.4906+04	6.2886+04	5.6379+04
15.50	1.6499+04	4.5602+04	4.2521+04
16.00	1.7939+04	3.9012+04	3.7800+04
16.50	1.8913+04	3.9125+04	3.8499+04
17.00	1.9793+04	4.3075+04	4.2279+04
17.50	2.0596+04	4.7734+04	4.6861+04
18.00	2.1413+04	5.1781+04	5.0779+04
18.50	2.2276+04	5.4205+04	5.2742+04
19.00	2.3330+04	5.4383+04	5.3192+04
19.50	2.4713+04	5.3211+04	5.2355+04
20.00	2.6537+04	5.1373+04	5.0805+04
20.50	2.8848+04	4.9290+04	4.9133+04
21.00	3.1581+04	4.7386+04	4.7345+04
21.50	3.4509+04	4.6132+04	4.6111+04
22.00	3.7431+04	4.4969+04	4.4963+04
22.50	3.8575+04	4.3529+04	4.3526+04
23.00	3.8692+04	4.1721+04	4.1720+04
23.50	3.8263+04	3.9910+04	3.9910+04
24.00	3.7465+04	3.8485+04	3.8485+04
24.50	3.6484+04	3.7181+04	3.7180+04
25.00	3.5456+04	3.5980+04	3.5977+04
25.50	3.4440+04	3.4907+04	3.4903+04
26.00	3.3524+04	3.3955+04	3.3938+04
26.50	3.2632+04	3.3033+04	3.3016+04
27.00	3.1808+04	3.2180+04	3.2163+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.0922+02	1.6120+04	7.5437+00	1.1604+04

1.8545-06	3.3157-03	3054	53	29	24

TABLE 17 (sheet 6 of 57)

THETA= 5.6009-01 EV = 1.1682+04 DEG R = 6.5000+03 DEG K

GAMMA= 1.9300+03

PRESSURE= 1.0153+08 (DYNE/CM2) = 1.0020+02 (ATM)

RHO= 4.3713-02 (G/CM3) = 2.7290+00 (LB/FT3)

ZBAR= 1.1822-02

UMAX	DELTA U
24.00	.38

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.38	1.2869+03	8.8567+03	8.0259+03
.77	1.9412+02	8.2430+03	7.0990+03
1.15	7.6565+01	9.6194+03	8.1033+03
1.54	4.3482+01	1.0524+04	9.1556+03
1.92	2.3596+01	1.1457+04	1.0138+04
2.31	2.1592+01	1.2472+04	1.1034+04
2.69	3.4399+01	1.3280+04	1.1753+04
3.08	3.0098+01	1.3808+04	1.2303+04
3.46	3.4773+01	1.4324+04	1.2572+04
3.85	4.4080+01	1.4633+04	1.2785+04
4.23	6.0830+01	1.4941+04	1.3031+04
4.62	9.0556+01	1.5711+04	1.3635+04
5.00	1.4199+02	1.7711+04	1.5376+04
5.38	2.2932+02	2.2189+04	1.9302+04
5.77	3.6047+02	3.0583+04	2.6923+04
6.15	5.5604+02	4.4574+04	3.9343+04
6.54	8.3564+02	6.2479+04	5.6735+04
6.92	1.2180+03	8.4098+04	7.7708+04
7.31	1.7201+03	1.1000+05	1.0293+05
7.69	2.3498+03	1.3874+05	1.3026+05
8.08	3.1199+03	1.6079+05	1.5077+05
8.46	4.0340+03	1.8363+05	1.7268+05
8.85	5.0876+03	2.0608+05	1.9402+05
9.23	6.2628+03	2.2142+05	2.0609+05
9.62	7.5204+03	2.1941+05	2.0696+05
10.00	8.8119+03	2.0489+05	1.9307+05
10.38	1.0124+04	1.7986+05	1.6873+05
10.77	1.1386+04	1.3013+05	1.2293+05
11.15	1.3066+04	9.0444+04	8.3570+04
11.54	1.4745+04	6.2349+04	5.8137+04
11.92	1.6307+04	4.5471+04	4.3685+04
12.31	1.7723+04	3.9016+04	3.8352+04
12.69	1.8684+04	3.9092+04	3.8728+04
13.08	1.9556+04	4.2896+04	4.2104+04
13.46	2.0355+04	4.7383+04	4.6254+04
13.85	2.1168+04	5.1274+04	4.9877+04
14.23	2.2027+04	5.3591+04	5.1709+04
14.62	2.3073+04	5.3723+04	5.2170+04
15.00	2.4442+04	5.2567+04	5.1493+04
15.38	2.6240+04	5.0779+04	5.0113+04
15.77	2.8510+04	4.8767+04	4.8558+04
16.15	3.1197+04	4.6952+04	4.6913+04
16.54	3.4069+04	4.5815+04	4.5794+04
16.92	3.6933+04	4.7041+04	4.7018+04
17.31	3.8059+04	5.1841+04	5.1574+04
17.69	3.8182+04	4.3939+04	4.3920+04
18.08	3.7771+04	3.9889+04	3.9888+04
18.46	3.7001+04	3.8668+04	3.8667+04
18.85	3.6053+04	4.8410+04	4.8341+04
19.23	3.5060+04	7.5598+04	6.9837+04
19.62	3.4078+04	4.5621+04	4.5537+04
20.00	3.3190+04	3.3905+04	3.3904+04
20.38	3.2324+04	3.2804+04	3.2804+04
20.77	3.1524+04	3.1986+04	3.1983+04
21.15	3.0793+04	3.1306+04	3.1291+04
21.54	3.0094+04	3.0690+04	3.0674+04
21.92	2.9440+04	2.9878+04	2.9874+04
22.31	2.8804+04	2.9161+04	2.9161+04
22.69	2.8214+04	2.8588+04	2.8587+04
23.08	2.7665+04	3.0063+04	3.0047+04
23.46	2.7152+04	3.4892+04	3.2688+04
23.85	2.6673+04	2.8951+04	2.8935+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
4.6680+02	2.6782+04	5.9037+01	1.5127+04

3.4890-05 2.2316-03 8630 250 220 30

TABLE 17 (sheet 7 of 57)

THETA= 5.6009-01 EV = 1.1682+04 DEG R = 6.5000+03 DEG K

GAMMA= 1.2970+03

PRESSURE= 2.0301+08 (DYNE/CM2) = 2.0036+02 (ATM)

RHO= 8.7645-02 (G/CM3) = 5.4716+00 (LB/FT3)

ZBAR= 8.7738-03

UMAX	DELTA U
24.00	.38

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.38	1.4197+03	8.7992+03	8.1496+03
.77	1.7835+02	8.2430+03	7.2729+03
1.15	6.9819+01	9.6418+03	8.3267+03
1.54	4.1427+01	1.0553+04	9.4367+03
1.92	2.2589+01	1.1490+04	1.0476+04
2.31	2.0799+01	1.2507+04	1.1411+04
2.69	3.3897+01	1.3317+04	1.2162+04
3.08	2.9770+01	1.3846+04	1.2740+04
3.46	3.4577+01	1.4362+04	1.3040+04
3.85	4.3989+01	1.4671+04	1.3293+04
4.23	6.0844+01	1.4978+04	1.3595+04
4.62	9.0700+01	1.5747+04	1.4290+04
5.00	1.4232+02	1.7749+04	1.6193+04
5.38	2.2996+02	2.2236+04	2.0377+04
5.77	3.6153+02	3.0652+04	2.8205+04
6.15	5.5773+02	4.4683+04	4.0887+04
6.54	8.3824+02	6.2643+04	5.8319+04
6.92	1.2218+03	8.4321+04	7.9685+04
7.31	1.7255+03	1.0991+05	1.0457+05
7.69	2.3572+03	1.3769+05	1.3119+05
8.08	3.1298+03	1.6085+05	1.5268+05
8.46	4.0468+03	1.8414+05	1.7507+05
8.85	5.1037+03	2.0668+05	1.9495+05
9.23	6.2827+03	2.2206+05	2.0844+05
9.62	7.5443+03	2.2003+05	2.0925+05
10.00	8.8400+03	2.0452+05	1.9423+05
10.38	1.0156+04	1.7686+05	1.6716+05
10.77	1.1422+04	1.2954+05	1.2413+05
11.15	1.3107+04	9.0687+04	8.5724+04
11.54	1.4790+04	6.2523+04	6.0092+04
11.92	1.6358+04	4.5594+04	4.4774+04
12.31	1.7779+04	3.9121+04	3.8836+04
12.69	1.8744+04	3.9198+04	3.8992+04
13.08	1.9619+04	4.3015+04	4.2060+04
13.46	2.0420+04	4.7519+04	4.5932+04
13.85	2.1235+04	5.1424+04	4.9401+04
14.23	2.2097+04	5.3749+04	5.1143+04
14.62	2.3147+04	5.3883+04	5.1710+04
15.00	2.4520+04	5.2725+04	5.1218+04
15.38	2.6324+04	5.0931+04	5.0041+04
15.77	2.8601+04	4.8913+04	4.8715+04
16.15	3.1296+04	4.7093+04	4.7053+04
16.54	3.4177+04	4.5951+04	4.5930+04
16.92	3.7050+04	4.7148+04	4.7126+04
17.31	3.8179+04	5.1876+04	5.1778+04
17.69	3.8303+04	4.4030+04	4.4012+04
18.08	3.7890+04	3.9986+04	3.9986+04
18.46	3.7117+04	3.8742+04	3.8740+04
18.85	3.6166+04	4.8281+04	4.8179+04
19.23	3.5170+04	7.5241+04	6.9536+04
19.62	3.4184+04	4.5606+04	4.5500+04
20.00	3.3293+04	3.4004+04	3.4003+04
20.38	3.2424+04	3.2903+04	3.2903+04
20.77	3.1621+04	3.2080+04	3.2080+04
21.15	3.0887+04	3.1380+04	3.1380+04
21.54	3.0186+04	3.0735+04	3.0735+04
21.92	2.9530+04	2.9954+04	2.9954+04
22.31	2.8892+04	2.9246+04	2.9246+04
22.69	2.8300+04	2.8663+04	2.8662+04
23.08	2.7749+04	3.0103+04	3.0087+04
23.46	2.7235+04	3.4884+04	3.2092+04
23.85	2.6753+04	2.8996+04	2.8980+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
4.6798+02	2.6813+04	5.7885+01	1.5698+04

3.2787-05	2.4035-03	7638	218	188	30

TABLE 17 (sheet 8 of 57)

THETA= 5.6009-01 EV = 1.1682+04 DEG R = 6.5000+03 DEG K

GAMMA= 7.5600+02

PRESSURE= 5.0910+08 (DYNE/CM2) = 5.0244+02 (ATM)

RHO= 2.2033-01 (G/CM3) = 1.3755+01 (LB/FT3)

ZBAR= 5.9877-03

UMAX	DELTA U
24.00	.38

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.38	1.6622+03	9.0644+03	8.6747+03
.77	2.0866+02	8.2981+03	7.6486+03
1.15	7.8854+01	9.6803+03	8.6996+03
1.54	4.5277+01	1.0588+04	9.7702+03
1.92	2.4564+01	1.1524+04	1.0899+04
2.31	2.0926+01	1.2545+04	1.1917+04
2.69	3.3563+01	1.3359+04	1.2693+04
3.08	3.0330+01	1.3892+04	1.3290+04
3.46	3.5014+01	1.4400+04	1.3627+04
3.85	4.3104+01	1.4707+04	1.3925+04
4.23	5.9064+01	1.5010+04	1.4233+04
4.62	8.7523+01	1.5781+04	1.5096+04
5.00	1.4289+02	1.7789+04	1.7122+04
5.38	2.3078+02	2.2286+04	2.1496+04
5.77	3.6276+02	3.0725+04	2.9642+04
6.15	5.5957+02	4.4797+04	4.2621+04
6.54	8.4096+02	6.2811+04	6.0150+04
6.92	1.2258+03	8.4549+04	8.1520+04
7.31	1.7310+03	1.0986+05	1.0528+05
7.69	2.3648+03	1.3677+05	1.3127+05
8.08	3.1398+03	1.6095+05	1.5345+05
8.46	4.0598+03	1.8467+05	1.7619+05
8.85	5.1201+03	2.0728+05	1.9633+05
9.23	6.3028+03	2.2272+05	2.0942+05
9.62	7.5684+03	2.2067+05	2.0995+05
10.00	8.8682+03	2.0424+05	1.9360+05
10.38	1.0169+04	1.7418+05	1.6577+05
10.77	1.1458+04	1.2904+05	1.2510+05
11.15	1.3149+04	9.0951+04	8.8044+04
11.54	1.4837+04	6.2747+04	6.1769+04
11.92	1.6410+04	4.5844+04	4.5576+04
12.31	1.7836+04	3.9219+04	3.9061+04
12.69	1.8803+04	3.9283+04	3.9093+04
13.08	1.9681+04	4.3137+04	4.1576+04
13.46	2.0485+04	4.7655+04	4.5153+04
13.85	2.1303+04	5.1581+04	4.8744+04
14.23	2.2168+04	5.3912+04	5.0969+04
14.62	2.3221+04	5.4045+04	5.2216+04
15.00	2.4598+04	5.2878+04	5.2222+04
15.38	2.6404+04	5.1076+04	5.0997+04
15.77	2.8690+04	4.9053+04	4.9013+04
16.15	3.1394+04	4.7227+04	4.7209+04
16.54	3.4286+04	4.6078+04	4.6070+04
16.92	3.7168+04	4.7148+04	4.7133+04
17.31	3.8300+04	5.1543+04	5.1408+04
17.69	3.8423+04	4.4012+04	4.3996+04
18.08	3.8009+04	4.0202+04	4.0202+04
18.46	3.7234+04	3.8851+04	3.8850+04
18.85	3.6280+04	4.7690+04	4.7599+04
19.23	3.5280+04	7.3213+04	6.6968+04
19.62	3.4290+04	4.5128+04	4.5034+04
20.00	3.3396+04	3.4095+04	3.4093+04
20.38	3.2525+04	3.3000+04	3.3000+04
20.77	3.1719+04	3.2171+04	3.2171+04
21.15	3.0982+04	3.1452+04	3.1452+04
21.54	3.0279+04	3.0781+04	3.0781+04
21.92	2.9620+04	3.0029+04	3.0029+04
22.31	2.8980+04	2.9328+04	2.9328+04
22.69	2.8386+04	2.8734+04	2.8734+04
23.08	2.7834+04	3.0057+04	3.0046+04
23.46	2.7318+04	3.4560+04	3.2165+04
23.85	2.6835+04	2.8955+04	2.8944+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
4.7095+02	2.6853+04	5.8820+01	1.6415+04

2.9283-05	2.3772-03	6770	167	144	23

TABLE 17 (sheet 9 of 57)

THETA= 5.6009-01 EV = 1.1682+04 DEG R = 6.5000+03 DEG K

GAMMA= 4.9800+02

PRESSURE= 1.0156+09 (DYNE/CM2) = 1.0023+03 (ATM)

RHO= 4.4009-01 (G/CM3) = 2.7475+01 (LB/FT3)

ZBAR= 4.5508-03

UMAX	DELTA U
23.00	.38

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.38	1.9177+03	9.3295+03	9.1275+03
.77	2.4061+02	8.3402+03	7.8871+03
1.15	8.8347+01	9.7018+03	8.9337+03
1.54	4.9300+01	1.0603+04	1.0045+04
1.92	2.6627+01	1.1537+04	1.1150+04
2.31	2.2130+01	1.2558+04	1.2237+04
2.69	3.4353+01	1.3371+04	1.3033+04
3.08	3.0871+01	1.3903+04	1.3631+04
3.46	3.5415+01	1.4409+04	1.4020+04
3.85	4.3424+01	1.4713+04	1.4353+04
4.23	5.9346+01	1.5012+04	1.4667+04
4.62	8.7806+01	1.5777+04	1.5514+04
5.00	1.4322+02	1.7780+04	1.7541+04
5.38	2.3123+02	2.2274+04	2.1892+04
5.77	3.6340+02	3.0716+04	3.0262+04
6.15	5.6051+02	4.4802+04	4.3589+04
6.54	8.4233+02	6.2838+04	6.1099+04
6.92	1.2277+03	8.4592+04	8.1942+04
7.31	1.7338+03	1.0918+05	1.0501+05
7.69	2.3685+03	1.3408+05	1.2954+05
8.08	3.1447+03	1.6032+05	1.5287+05
8.46	4.0662+03	1.8483+05	1.7650+05
8.85	5.1281+03	2.0748+05	1.9580+05
9.23	6.3127+03	2.2294+05	2.0847+05
9.62	7.5803+03	2.2086+05	2.0934+05
10.00	8.8821+03	2.0257+05	1.8969+05
10.38	1.0205+04	1.6751+05	1.6005+05
10.77	1.1476+04	1.2727+05	1.2346+05
11.15	1.3170+04	9.0996+04	8.9239+04
11.54	1.4860+04	6.2788+04	6.2236+04
11.92	1.6436+04	4.5865+04	4.5607+04
12.31	1.7864+04	3.9232+04	3.9098+04
12.69	1.8833+04	3.9299+04	3.9152+04
13.08	1.9712+04	4.3161+04	4.1054+04
13.46	2.0517+04	4.7687+04	4.4071+04
13.85	2.1337+04	5.1618+04	4.7392+04
14.23	2.2202+04	5.3948+04	4.9824+04
14.62	2.3257+04	5.4074+04	5.1426+04
15.00	2.4635+04	5.2889+04	5.1871+04
15.38	2.6444+04	5.1064+04	5.0986+04
15.77	2.8732+04	4.9012+04	4.8973+04
16.15	3.1440+04	4.7147+04	4.7130+04
16.54	3.4335+04	4.5912+04	4.5905+04
16.92	3.7220+04	4.4774+04	4.4774+04
17.31	3.8353+04	4.3358+04	4.3358+04
17.69	3.8474+04	4.1577+04	4.1577+04
18.08	3.8057+04	3.9917+04	3.9917+04
18.46	3.7279+04	3.8429+04	3.8429+04
18.85	3.6320+04	3.7084+04	3.7084+04
19.23	3.5316+04	3.5898+04	3.5898+04
19.62	3.4322+04	3.4837+04	3.4837+04
20.00	3.3424+04	3.3893+04	3.3893+04
20.38	3.2545+04	3.2978+04	3.2978+04
20.77	3.1738+04	3.2130+04	3.2130+04
21.15	3.0997+04	3.1353+04	3.1353+04
21.54	3.0291+04	3.0612+04	3.0611+04
21.92	2.9630+04	2.9916+04	2.9902+04
22.31	2.8987+04	2.9239+04	2.9225+04
22.69	2.8391+04	2.8611+04	2.8597+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
4.7388+02	2.6794+04	6.0760+01	1.6845+04

5.3386-05 3.4242-03 2770 59 42 17

TABLE 17 (sheet 10 of 57)

THETA= 6.8935-01 EV = 1.4378+04 DEG R = 8.0000+03 DEG K

GAMMA= 8.4300+02

PRESSURE= 1.0128+08 (DYNE/CM2) = 9.9952+01 (ATM)

RHO= 3.4524-02 (G/CM3) = 2.1553+00 (LB/FT3)

ZBAR= 4.6792-02

UMAX	DELTA U
22.00	.63

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.63	1.7960+03	9.9636+03	9.3246+03
1.25	2.9934+02	1.0430+04	9.3687+03
1.88	1.0594+02	1.1801+04	1.1196+04
2.50	1.4488+02	1.3583+04	1.2871+04
3.13	1.1232+02	1.4702+04	1.3988+04
3.75	1.6304+02	1.6019+04	1.5583+04
4.38	3.2508+02	2.2762+04	2.2132+04
5.00	7.0973+02	4.2392+04	3.9757+04
5.63	1.4251+03	7.4662+04	7.1128+04
6.25	2.5604+03	1.2042+05	1.1425+05
6.88	4.1729+03	1.3753+05	1.3147+05
7.50	6.2576+03	1.7713+05	1.6942+05
8.13	8.6029+03	2.26[illegible]5	2.0192+05
8.75	1.0972+04	1.5[illegible]5	1.4696+05
9.38	1.4044+04	8.7[illegible]04	8.4465+04
10.00	1.6664+04	4.96[illegible]+04	4.9418+04
10.63	1.8468+04	4.4845+04	4.3812+04
11.25	2.0043+04	4.9375+04	4.[illegible]+04
11.88	2.1773+04	4.8019+04	[illegible]+04
12.50	2.4351+04	4.3971+04	4.3883+04
13.13	2.8204+04	4.2412+04	4.2391+04
13.75	3.2552+04	5.7536+04	5.3971+04
14.38	3.4760+04	4.1248+04	4.1245+04
15.00	3.4584+04	4.2176+04	4.2152+04
15.63	3.3323+04	1.2365+05	9.3915+04
16.25	3.1813+04	3.6353+04	3.6331+04
16.87	3.0390+04	3.2290+04	3.2290+04
17.50	2.9102+04	3.1610+04	3.1610+04
18.12	2.7910+04	3.1117+04	3.1107+04
18.75	2.6839+04	7.0594+04	5.2359+04
19.37	2.5908+04	2.7848+04	2.7840+04
20.00	2.5090+04	2.5559+04	2.5559+04
20.62	2.4370+04	2.4807+04	2.4808+04
21.25	2.4064+04	2.4111+04	2.4111+04
21.88	2.3001+04	2.3019+04	2.3019+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.2636+03	3.7803+04	2.5340+02	2.0365+04

2.4192-04	3.0812-03	3849	179	143	36

TABLE 17 (sheet 11 of 57)

THETA= 6.8935-01 EV = 1.4378+04 DEG R = 8.0000+03 DEG K

GAMMA= 5.5500+02

PRESSURE= 2.0179+08 (DYNE/CM2) = 1.9915+02 (ATM)

RHO= 6.9475-02 (G/CM3) = 4.3373+00 (LB/FT3)

ZBAR= 3.5318-02

UMAX	DELTA U
22.00	.63

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.63	2.0584+03	1.0330+04	9.7612+03
1.25	3.3326+02	1.0589+04	9.7158+03
1.88	1.1620+02	1.1952+04	1.1611+04
2.50	1.5069+02	1.3745+04	1.3297+04
3.13	1.1586+02	1.4871+04	1.4361+04
3.75	1.6653+02	1.6168+04	1.5979+04
4.38	3.3058+02	2.2944+04	2.2626+04
5.00	7.2075+02	4.2780+04	4.0567+04
5.63	1.4466+03	7.5321+04	7.2318+04
6.25	2.5987+03	1.1825+05	1.1161+05
6.88	4.2351+03	1.3899+05	1.3311+05
7.50	6.3508+03	1.7925+05	1.7007+05
8.13	8.7309+03	2.2063+05	2.0029+05
8.75	1.1135+04	1.5454+05	1.4775+05
9.38	1.4253+04	8.8534+04	8.6523+04
10.00	1.6911+04	5.0330+04	5.0154+04
10.63	1.8743+04	4.5429+04	4.3983+04
11.25	2.0341+04	5.0025+04	4.5650+04
11.88	2.2096+04	4.8636+04	4.5881+04
12.50	2.4711+04	4.4498+04	4.4410+04
13.13	2.8619+04	4.2774+04	4.2755+04
13.75	3.3028+04	5.6111+04	5.3312+04
14.38	3.5264+04	4.1375+04	4.1373+04
15.00	3.5079+04	4.1805+04	4.1787+04
15.63	3.3792+04	1.1425+05	8.6306+04
16.25	3.2254+04	3.6335+04	3.6318+04
16.87	3.0804+04	3.2514+04	3.2514+04
17.50	2.9492+04	3.1699+04	3.1699+04
18.12	2.8280+04	3.1146+04	3.1137+04
18.75	2.7192+04	6.6132+04	4.6356+04
19.37	2.6246+04	2.7967+04	2.7959+04
20.00	2.5414+04	2.5819+04	2.5819+04
20.62	2.4680+04	2.5057+04	2.5057+04
21.25	2.4307+04	2.4351+04	2.4351+04
21.88	2.3258+04	2.3276+04	2.3276+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.2912+03	3.7926+04	2.6433+02	2.0971+04

2.2631-04	3.3177-03	3359	179	144	35

TABLE 17 (sheet 12 of 57)

THETA= 6.8935-01 EV = 1.4378+04 DEG R = 8.0000+03 DEG K

GAMMA= 3.1400+02

PRESSURE= 5.0667+08 (DYNE/CM2) = 5.0004+02 (ATM)

RHO= 1.7606-01 (G/CM3) = 1.0992+01 (LB/FT3)

ZBAR= 2.4633-02

UMAX	DELTA U
21.00	.63

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.63	2.5348+03	1.0499+04	1.0394+04
1.25	3.1896+02	1.0656+04	1.0565+04
1.88	1.0817+02	1.2047+04	1.1939+04
2.50	1.5196+02	1.3860+04	1.3770+04
3.13	1.1510+02	1.4989+04	1.4886+04
3.75	1.6693+02	1.6267+04	1.6178+04
4.38	3.3322+02	2.3060+04	2.2921+04
5.00	7.4797+02	4.3040+04	4.1937+04
5.63	1.4621+03	7.5756+04	7.3200+04
6.25	2.6272+03	1.1597+05	1.1097+05
6.88	4.2820+03	1.4003+05	1.3394+05
7.50	6.4215+03	1.8064+05	1.6807+05
8.13	8.8283+03	2.1508+05	1.9358+05
8.75	1.1259+04	1.5586+05	1.4714+05
9.38	1.4412+04	8.9441+04	8.8302+04
10.00	1.7101+04	5.0823+04	5.0560+04
10.63	1.8953+04	4.5875+04	4.3873+04
11.25	2.0568+04	5.0531+04	4.4188+04
11.88	2.2343+04	4.9133+04	4.5323+04
12.50	2.4986+04	4.4950+04	4.4866+04
13.13	2.8935+04	4.3199+04	4.3183+04
13.75	3.3392+04	5.6582+04	5.4680+04
14.38	3.5647+04	4.1719+04	4.1715+04
15.00	3.5453+04	4.1903+04	4.1889+04
15.63	3.4144+04	1.1491+05	8.3395+04
16.25	3.2580+04	3.6664+04	3.6636+04
16.87	3.1104+04	3.2789+04	3.2789+04
17.50	2.9767+04	3.1886+04	3.1886+04
18.12	2.8530+04	3.1388+04	3.1379+04
18.75	2.7421+04	6.6480+04	4.1328+04
19.37	2.6454+04	2.8151+04	2.8143+04
20.00	2.5603+04	2.5974+04	2.5974+04
20.62	2.4839+04	2.5185+04	2.5185+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.3132+03	3.7945+04	2.6113+02	2.1640+04

3.7899-04	3.6025-03	2614	146	117	29

TABLE 17 (sheet 13 of 57)

THETA= 6.8935-01 EV = 1.4378+04 DEG R = 8.0000+03 DEG K

GAMMA= 2.0100+02

PRESSURE= 1.0156+09 (DYNE/CM2) = 1.0023+03 (ATM)

RHO= 3.5460-01 (G/CM3) = 2.2137+01 (LB/FT3)

ZBAR= 1.9107-02

UMAX	DELTA U
21.00	.63

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.63	3.0712+03	1.1081+04	1.1018+04
1.25	3.8603+02	1.0782+04	1.0712+04
1.88	1.2814+02	1.2134+04	1.2049+04
2.50	1.6109+02	1.3942+04	1.3823+04
3.13	1.2003+02	1.5072+04	1.4967+04
3.75	1.7046+02	1.6339+04	1.6258+04
4.38	3.3701+02	2.3146+04	2.2949+04
5.00	7.3397+02	4.3223+04	4.2810+04
5.63	1.4728+03	7.6064+04	7.5105+04
6.25	2.6457+03	1.1492+05	1.1150+05
6.88	4.3118+03	1.4073+05	1.3542+05
7.50	6.4658+03	1.8156+05	1.6650+05
8.13	8.8891+03	2.1243+05	1.8817+05
8.75	1.1337+04	1.5672+05	1.4651+05
9.38	1.4511+04	9.0007+04	8.9354+04
10.00	1.7218+04	5.1131+04	5.0913+04
10.63	1.9083+04	4.6151+04	4.3977+04
11.25	2.0709+04	5.0839+04	4.3086+04
11.88	2.2495+04	4.9426+04	4.4754+04
12.50	2.5156+04	4.5202+04	4.5122+04
13.13	2.9132+04	4.3378+04	4.3349+04
13.75	3.3617+04	5.5987+04	5.5422+04
14.38	3.5886+04	4.1792+04	4.1789+04
15.00	3.5687+04	4.1747+04	4.1722+04
15.63	3.4366+04	1.1086+05	7.7116+04
16.25	3.2789+04	3.6674+04	3.6653+04
16.87	3.1300+04	3.2902+04	3.2902+04
17.50	2.9951+04	3.1935+04	3.1935+04
18.12	2.8705+04	3.1415+04	3.1405+04
18.75	2.7587+04	6.4561+04	3.7606+04
19.37	2.6614+04	2.8215+04	2.8205+04
20.00	2.5757+04	2.6098+04	2.6098+04
20.62	2.4987+04	2.5305+04	2.5305+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.3415+03	3.8013+04	2.7813+02	2.1838+04

3.1565-04	3.7500-03	2218	145	119	26

TABLE 17 (sheet 14 of 57)

THETA= 8.6168-01 EV = 1.7972+04 DEG R = 1.0000+04 DEG K

GAMMA= 4.4400+02

PRESSURE= 1.0132+08 (DYNE/CM2) = 9.9996+01 (ATM)

RHO= 2.5453-02 (G/CM3) = 1.5894+00 (LB/FT3)

ZBAR= 1.6837-01

UMAX	DELTA U
20.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	1.5498+04	2.4945+04	2.4774+04
1.00	1.9425+03	1.3778+04	1.3729+04
1.50	6.2038+02	1.2227+04	1.2134+04
2.00	6.0434+02	1.4278+04	1.3363+04
2.50	3.6384+02	1.5265+04	1.4671+04
3.00	3.5419+02	1.7052+04	1.6960+04
3.50	4.9992+02	2.4266+04	2.4105+04
4.00	9.1505+02	4.1979+04	4.0729+04
4.50	1.6477+03	7.0963+04	7.0586+04
5.00	2.7084+03	1.3248+05	1.1675+05
5.30	4.1077+03	1.2299+05	1.2152+05
6.00	5.8778+03	1.5424+05	1.4988+05
6.50	7.8450+03	2.4449+05	1.8244+05
7.00	9.8043+03	1.2955+05	1.2887+05
7.50	1.2333+04	7.5106+04	7.4503+04
8.00	1.4519+04	4.4901+04	4.4673+04
8.50	1.6088+04	4.0827+04	3.9699+04
9.00	1.7512+04	4.4282+04	4.0211+04
9.50	1.9121+04	4.3450+04	4.1455+04
10.00	2.1368+04	4.1186+04	4.1118+04
10.50	2.4606+04	4.3225+04	4.3157+04
11.00	2.8200+04	7.6065+04	6.5101+04
11.50	3.0107+04	4.7582+04	4.7456+04
12.00	3.0146+04	5.0666+04	5.0562+04
12.50	2.9330+04	2.0921+05	1.4554+05
13.00	2.8286+04	4.0403+04	4.0336+04
13.50	2.7284+04	3.5528+04	3.5480+04
14.00	2.6347+04	3.7085+04	3.7004+04
14.50	2.5398+04	3.5995+04	3.5947+04
15.00	2.4526+04	1.1226+05	5.9679+04
15.50	2.3778+04	2.8259+04	2.8237+04
16.00	2.3133+04	2.4488+04	2.4486+04
16.50	2.2574+04	2.4063+04	2.4060+04
17.00	2.2784+04	2.4025+04	2.4018+04
17.50	2.1658+04	2.3809+04	2.3790+04
18.00	2.0909+04	2.4351+04	2.4331+04
18.50	1.9879+04	2.5021+04	2.4984+04
19.00	1.8933+04	2.5804+04	2.5739+04
19.50	1.8067+04	2.5188+04	2.5150+04
20.00	1.7268+04	2.2209+04	2.2161+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
2.8250+03	5.3300+04	9.0876+02	2.8741+04

1.8674-03 4.0638-03 3943 246 199 47

TABLE 17 (sheet 15 of 57)

THETA= 8.6168-01 EV = 1.7972+04 DEG R = 1.0000+04 DEG K

GAMMA= 2.8000+02

PRESSURE= 2.0285+08 (DYNE/CM2) = 2.0020+02 (ATM)

RHO= 5.2632-02 (G/CM3) = 3.2858+00 (LB/F/3)

ZBAR= 1.2915-01

UMAX	DELTA U
20.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	1.8815+04	2.8418+04	2.8375+04
1.00	2.3575+03	1.4486+04	1.4442+04
1.50	7.4539+02	1.2606+04	1.2506+04
2.00	6.7121+02	1.4614+04	1.3789+04
2.50	4.0103+02	1.5725+04	1.5221+04
3.00	3.6174+02	1.7365+04	1.7253+04
3.50	5.3050+02	2.4484+04	2.4321+04
4.00	9.6321+02	4.2409+04	4.2115+04
4.50	1.7299+03	7.1836+04	7.1365+04
5.00	2.8408+03	1.2676+05	1.1272+05
5.50	4.3069+03	1.2587+05	1.2325+05
6.00	6.1622+03	1.5855+05	1.5220+05
6.50	8.2239+03	2.3177+05	1.8850+05
7.00	1.0278+04	1.3423+05	1.3351+05
7.50	1.2928+04	7.8272+04	7.7905+04
8.00	1.5220+04	4.6673+04	4.6486+04
8.50	1.6865+04	4.2420+04	4.1726+04
9.00	1.8355+04	4.6074+04	4.1414+04
9.50	2.0038+04	4.5212+04	4.3380+04
10.00	2.2381+04	4.2800+04	4.2741+04
10.50	2.5758+04	4.4808+04	4.4755+04
11.00	2.9502+04	7.8317+04	6.8792+04
11.50	3.1469+04	4.9036+04	4.8943+04
12.00	3.1471+04	5.1512+04	5.1400+04
12.50	3.0575+04	2.[illegible]21+05	1.4115+05
13.00	2.9444+04	4.[illegible]20+04	4.1680+04
13.50	2.8362+04	3.6642+04	3.6615+04
14.00	2.7356+04	3.8018+04	3.7959+04
14.50	2.6347+04	3.7085+04	3.7023+04
15.00	2.5428+04	1.1492+05	5.2208+04
15.50	2.4639+04	2.9115+04	2.9088+04
16.00	2.3959+04	2.5235+04	2.5234+04
16.50	2.3367+04	2.4804+04	2.4802+04
17.00	2.3490+04	2.4771+04	2.4762+04
17.50	2.2356+04	2.4577+04	2.4566+04
18.00	2.1546+04	2.5008+04	2.4983+04
18.50	2.0464+04	2.5359+04	2.5337+04
19.00	1.9509+04	2.5587+04	2.5550+04
19.50	1.8616+04	2.4614+04	2.4574+04
20.00	1.7791+04	2.1853+04	2.1827+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
3.0086+03	5.3610+04	9.8688+02	2.9559+04

1.5819-03	4.2300-03	3463	245	261	44

TABLE 17 (sheet 16 of 57)

THETA= 8.6168-01 EV = 1.7972+04 DEG R = 1.0000+04 DEG K

GAMMA= 1.5000+02

PRESSURE= 5.0897+08 (DYNE/CM2) = 5.0232+02 (ATM)

RHO= 1.3612-01 (G/CM3) = 8.4978+00 (LB/FT3)

ZBAR= 9.3214-02

UMAX	DELTA U
19.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	2.5318+04	3.5214+04	3.5174+04
1.00	3.1706+03	1.5691+04	1.5620+04
1.50	9.8880+02	1.3187+04	1.3136+04
2.00	7.9280+02	1.5095+04	1.4967+04
2.50	4.6602+02	1.6302+04	1.6200+04
3.00	4.2682+02	1.7796+04	1.7695+04
3.50	5.7406+02	2.4874+04	2.4727+04
4.00	1.0243+03	4.3149+04	4.2843+04
4.50	1.8284+03	7.3219+04	7.2902+04
5.00	2.9960+03	1.2237+05	1.1021+05
5.50	4.5382+03	1.2965+05	1.2400+05
6.00	6.4909+03	1.6399+05	1.5064+05
6.50	8.6610+03	2.2165+05	1.7374+05
7.00	1.0823+04	1.3980+05	1.3142+05
7.50	1.3614+04	8.1885+04	8.1328+04
8.00	1.6026+04	4.8672+04	4.8521+04
8.50	1.7758+04	4.4197+04	4.3285+04
9.00	1.9324+04	4.7991+04	4.1223+04
9.50	2.1091+04	4.6958+04	4.3389+04
10.00	2.3547+04	4.4165+04	4.4104+04
10.50	2.7085+04	4.5451+04	4.5408+04
11.00	3.1002+04	7.4081+04	7.0375+04
11.50	3.3039+04	4.8572+04	4.8507+04
12.00	3.3000+04	5.0090+04	4.9994+04
12.50	3.2012+04	1.8995+05	1.2213+05
13.00	3.0781+04	4.1380+04	4.1342+04
13.50	2.9604+04	3.6728+04	3.6706+04
14.00	2.8513+04	3.7600+04	3.7564+04
14.50	2.7430+04	3.6659+04	3.6611+04
15.00	2.6448+04	1.0335+05	4.2820+04
15.50	2.5602+04	2.9432+04	2.9418+04
16.00	2.4867+04	2.5962+04	2.5961+04
16.50	2.4216+04	2.5508+04	2.5506+04
17.00	2.4157+04	2.5465+04	2.5457+04
17.50	2.3052+04	2.5281+04	2.5271+04
18.00	2.2103+04	2.5350+04	2.5331+04
18.50	2.0995+04	2.4652+04	2.4629+04
19.00	1.9980+04	2.3133+04	2.3112+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
3.2715+03	5.3957+04	1.1098+03	3.0807+04

2.3816-03	4.1848-03	2926	727	191	36

TABLE 17 (sheet 17 of 57)

THETA= 8.6168-01 EV = 1.7972+04 DEG R = 1.0000+04 DEG K

GAMMA= 9.3000+01

PRESSURE= 1.0140+09 (DYNE/CM2) = 1.0007+03 (ATM)

RHO= 2.7566-01 (G/CM3) = 1.7210+01 (LB/FT3)

ZBAR= 7.4238-02

UMAX	DELTA U
19.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	3.2517+04	4.2225+04	4.2185+04
1.00	4.0696+03	1.6671+04	1.6598+04
1.50	1.2345+03	1.3558+04	1.3508+04
2.00	9.0727+02	1.[illegible]345+0	1.5223+04
2.50	5.0640+02	1.6555+04	1.6465+04
3.00	4.6202+02	1.7978+04	1.7904+04
3.50	6.0301+02	2.5005+04	2.4797+04
4.00	1.0573+03	4.3390+04	4.3186+04
4.50	1.8759+03	7.3720+04	7.3090+04
5.00	3.0669+03	1.1964+05	1.0569+05
5.50	4.6417+03	1.3113+05	1.2194+05
6.00	6.6364+03	1.6619+05	1.4044+05
6.50	8.8534+03	2.1562+05	1.5424+05
7.00	1.1063+04	1.4216+05	1.2261+05
7.50	1.3914+04	8.3471+04	8.2963+04
8.00	1.6380+04	4.9554+04	4.9344+04
8.50	1.8149+04	4.4993+04	4.4954+04
9.00	1.9748+04	4.8881+04	4.8862+04
9.50	2.1552+04	4.7823+04	4.7815+04
10.00	2.4057+04	4.4941+04	4.4932+04
10.50	2.7647+04	4.6145+04	4.6122+04
11.00	3.1656+04	7.4725+04	7.3110+04
11.50	3.3724+04	4.9214+04	4.9159+04
12.00	3.3667+04	5.0349+04	5.0241+04
12.50	3.2638+04	1.9030+05	1.0294+05
13.00	3.1364+04	4.1901+04	4.1870+04
13.50	3.0145+04	3.7201+04	3.7200+04
14.00	2.9020+04	3.7961+04	3.7961+04
14.50	2.7905+04	3.7086+04	3.7086+04
15.00	2.6901+04	1.0364+05	1.0364+05
15.50	2.6033+04	2.9815+04	2.9815+04
16.00	2.5280+04	2.6330+04	2.6329+04
16.50	2.4612+04	2.5872+04	2.5870+04
17.00	2.4504+04	2.5832+04	2.5826+04
17.50	2.3378+04	2.5670+04	2.5655+04
18.00	2.2415+04	2.5725+04	2.5702+04
18.50	2.1291+04	2.5021+04	2.4992+04
19.00	2.0261+04	2.3477+04	2.3452+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
3.4642+03	5.4126+04	1.1964+03	3.1[illegible]90+04

1.8834-03 3.9373-03 2625 167 139 28

TABLE 17 (sheet 18 of 57)

THETA= 1.1202+00 EV = 2.3364+04 DEG R = 1.3000+04 DEG K

GAMMA= 3.2500+02

PRESSURE= 1.0125+06 (DYNE/CM2) = 9.9924+01 (ATM)

RHO= 1.5676-02 (G/CM3) = 9.7864-01 (LB/FT3)

ZBAR= 5.5372-01

UMAX	DELTA U
18.00	.38

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.38	9.9796+04	1.1749+05	1.1653+05
.77	1.2484+04	3.3532+04	3.3496+04
1.15	3.7941+03	2.0225+04	1.8392+04
1.54	2.3354+03	2.2622+04	1.6690+04
1.92	1.2469+03	1.6760+04	1.6671+04
2.31	9.3917+02	1.9366+04	1.9220+04
2.69	8.7631+02	2.8235+04	2.8050+04
3.08	1.1612+03	4.5745+04	4.5366+04
3.46	1.6951+03	7.0063+04	6.9425+04
3.85	2.3906+03	1.3733+05	9.8499+04
4.23	3.1801+03	9.6103+04	9.5316+04
4.62	4.1276+03	1.0707+05	1.0640+05
5.00	5.1663+03	2.2562+05	1.5045+05
5.38	6.1590+03	7.7320+04	7.6987+04
5.77	7.4282+03	4.6403+04	4.6144+04
6.15	8.5645+03	3.2587+04	3.2449+04
6.54	9.4604+03	2.9953+04	2.9880+04
6.92	1.0354+04	3.1370+04	3.1271+04
7.31	1.1444+04	3.1541+04	3.1431+04
7.69	1.2866+04	3.3820+04	3.3769+04
8.08	1.4753+04	3.9990+04	3.9838+04
8.46	1.6821+04	7.3222+04	6.3920+04
8.85	1.8172+04	5.1271+04	5.1141+04
9.23	1.8754+04	5.3114+04	5.2926+04
9.62	1.8948+04	1.8940+05	1.3979+05
10.00	1.8934+04	3.9835+04	3.9776+04
10.38	1.8873+04	3.8027+04	3.7918+04
10.77	1.8725+04	4.2865+04	4.2718+04
11.15	1.8392+04	3.9238+04	3.9133+04
11.54	1.8010+04	1.0371+05	4.7039+04
11.92	1.7684+04	2.6921+04	2.6892+04
12.31	1.7419+04	3.5378+04	3.5277+04
12.69	1.7180+04	2.3393+04	2.3388+04
13.08	1.7751+04	2.6301+04	2.6279+04
13.46	1.6883+04	5.8074+04	5.5510+04
13.85	1.6529+04	2.9648+04	2.9596+04
14.23	1.5817+04	3.2535+04	3.2443+04
14.62	1.5173+04	4.3903+04	4.3457+04
15.00	1.4587+04	4.4031+04	4.3875+04
15.38	1.4054+04	3.9202+04	3.9003+04
15.77	1.3551+04	3.2045+04	3.1940+04
16.15	1.3057+04	2.9761+04	2.9663+04
16.54	1.2554+04	2.6532+04	2.6468+04
16.92	1.2076+04	2.5550+04	2.5476+04
17.31	1.1496+04	2.4663+04	2.4592+04
17.69	1.0948+04	2.1724+04	2.1660+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
4.3350+03	6.0452+04	2.3659+03	3.7305+04

1.3306-04 3.6533-03 6470 361 301 60

TABLE 17 (sheet 19 of 57)

THETA= 1.1202+00 EV = 2.3364+04 DEG R = 1.3000+04 DEG K

GAMMA= 1.8600+02

PRESSURE= 2.0295+08 (DYNE/CM2) = 2.0030+02 (ATM)

RHO= 3.3978-02 (G/CM3) = 2.1213+00 (LB/FT3)

ZBAR= 4.4636-01

UMAX	DELTA U
18.00	.38

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.38	1.3826+05	1.5478+05	1.5227+05
.77	1.7293+04	3.8801+04	3.8763+04
1.15	5.2385+03	2.1469+04	2.1090+04
1.54	3.0931+03	2.2925+04	1.7914+04
1.92	1.6338+03	1.8169+04	1.8064+04
2.31	1.1918+03	2.0302+04	2.0172+04
2.69	1.0869+03	2.8651+04	2.8525+04
3.08	1.4085+03	4.5757+04	4.5486+04
3.46	2.0406+03	7.0444+04	6.9885+04
3.85	2.8669+03	1.3129+05	1.0415+05
4.23	3.8090+03	1.0078+05	9.9948+04
4.62	4.9464+03	1.1499+05	1.1413+05
5.00	6.1897+03	2.1502+05	1.5404+05
5.38	7.3824+03	8.6964+04	8.6574+04
5.77	8.9066+03	5.2954+04	5.2742+04
6.15	1.0271+04	3.6295+04	3.6199+04
6.54	1.1345+04	3.3490+04	3.3377+04
6.92	1.2404+04	3.5487+04	3.5402+04
7.31	1.3681+04	3.5826+04	3.5708+04
7.69	1.5313+04	3.7915+04	3.7859+04
8.08	1.7467+04	4.5946+04	4.5780+04
8.46	1.9811+04	8.5906+04	7.8514+04
8.85	2.1259+04	5.9214+04	5.9069+04
9.23	2.1756+04	6.0016+04	5.9900+04
9.62	2.1786+04	2.2568+05	1.4112+05
10.00	2.1596+04	4.5750+04	4.5664+04
10.38	2.1372+04	4.3339+04	4.3241+04
10.77	2.1083+04	4.8630+04	4.8494+04
11.15	2.0619+04	4.4637+04	4.4437+04
11.54	2.0136+04	1.2195+05	4.6047+04
11.92	1.9725+04	2.9193+04	2.9155+04
12.31	1.9391+04	3.4605+04	3.4525+04
12.69	1.9088+04	2.4714+04	2.4705+04
13.08	1.9599+04	2.7103+04	2.7068+04
13.46	1.8651+04	5.3373+04	4.7374+04
13.85	1.8217+04	3.0476+04	3.0404+04
14.23	1.7429+04	3.2962+04	3.2871+04
14.62	1.6714+04	4.1636+04	4.1465+04
15.00	1.6063+04	4.1995+04	4.1806+04
15.38	1.5468+04	3.7882+04	3.7720+04
15.77	1.4905+04	3.1995+04	3.1909+04
16.15	1.4351+04	3.0253+04	3.0161+04
16.54	1.3783+04	2.7587+04	2.7520+04
16.92	1.3246+04	2.6637+04	2.6559+04
17.31	1.2582+04	2.5457+04	2.5367+04
17.69	1.1957+04	2.2482+04	2.2323+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
5.3174+03	6.2162+04	2.9213+03	4.0307+04

1.2310-02	3.7456-03	5832	334	279	55

TABLE 17 (sheet 20 of 57)

THETA= 1.1202+00 EV = 2.3364+04 DEG R = 1.3000+04 DEG K

GAMMA= 8.8000+01

PRESSURE= 5.1215+08 (DYNE/CM2) = 5.0545+02 (ATM)

RHO= 9.3290-02 (G/C43) = 5.8241+00 (LB/FT3)

ZBAR= 3.4363-01

UMAX	DELTA U
18.00	.36

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.38	2.2298+05	2.3738+05	2.3430+05
.77	2.7883+04	4.9467+04	4.9424+04
1.15	8.3336+03	2.4558+04	2.4498+04
1.54	4.6084+03	2.4391+04	2.1740+04
1.92	2.4104+03	2.0485+04	2.0337+04
2.31	1.6519+03	2.2014+04	2.1940+04
2.69	1.4481+03	2.9981+04	2.9835+04
3.08	1.7921+03	4.7141+04	4.6811+04
3.46	2.5391+03	7.3035+04	7.1980+04
3.85	3.5343+03	1.2855+05	9.9304+04
4.23	4.6779+03	1.0926+05	1.0533+05
4.62	6.0683+03	1.2763+05	1.1521+05
5.00	7.5865+03	2.0978+05	1.2587+05
5.38	9.0476+03	1.0054+05	9.9355+04
5.77	1.0915+04	6.1804+04	6.1606+04
6.15	1.2588+04	4.1371+04	4.1300+04
6.54	1.3900+04	3.8084+04	3.8021+04
6.92	1.5182+04	4.0223+04	4.0203+04
7.31	1.6711+04	4.0009+04	3.9988+04
7.69	1.8631+04	4.0772+04	4.0744+04
8.08	2.1149+04	4.6975+04	4.6925+04
8.46	2.3867+04	7.9558+04	7.8537+04
8.85	2.5446+04	5.7342+04	5.7144+04
9.23	2.5822+04	5.7456+04	5.7326+04
9.62	2.5618+04	1.9305+05	9.3991+04
10.00	2.5173+04	4.5082+04	4.5048+04
10.38	2.4705+04	4.2752+04	4.2751+04
10.77	2.4204+04	4.6757+04	4.6757+04
11.15	2.3545+04	4.3200+04	4.3200+04
11.54	2.2903+04	1.0635+05	1.0635+05
11.92	2.2352+04	3.0009+04	3.0006+04
12.31	2.1894+04	3.3699+04	3.3638+04
12.69	2.1469+04	2.6259+04	2.6252+04
13.08	2.1703+04	2.8304+04	2.8282+04
13.46	2.0730+04	4.8684+04	4.0010+04
13.85	2.0120+04	3.2042+04	3.2000+04
14.23	1.9251+04	3.4330+04	3.4242+04
14.62	1.8461+04	4.0768+04	4.0640+04
15.00	1.7739+04	4.0920+04	4.0779+04
15.38	1.7079+04	3.7469+04	3.7350+04
15.77	1.6451+04	3.2868+04	3.2796+04
16.15	1.5831+04	3.1692+04	3.1613+04
16.54	1.5190+04	2.9571+04	2.9503+04
16.92	1.4584+04	2.8580+04	2.8362+04
17.31	1.3822+04	2.6964+04	2.6575+04
17.69	1.3104+04	2.3820+04	2.3362+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
6.9192+03	6.5383+04	3.8158+03	4.3854+04

8.3045-03	3.7479-03	4618	259	217	42

TABLE 17 (sheet 21 of 57)

THETA= 1.1202+00 EV = 2.3364+04 DEG R = 1.3000+04 DEG K

GAMMA= 5.1000+01

PRESSURE= 1.0091+09 (DYNE/CM2) = 9.9593+02 (ATM)

RHO= 1.9373-01 (G/CM3) = 1.2094+01 (LB/FT3)

ZBAR= 2.8553-01

UMAX	DELTA U
17.00	.38

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.38	3.2053+05	3.3225+05	3.3201+05
.77	4.0077+04	5.0223+04	5.0197+04
1.15	1.1901+04	2.6047+04	2.5981+04
1.54	5.0917+03	2.4529+04	2.4466+04
1.92	2.6084+03	2.1575+04	2.1479+04
2.31	1.6325+03	2.2589+04	2.2461+04
2.69	1.6049+03	2.9126+04	2.8935+04
3.08	1.9597+03	4.7287+04	4.7035+04
3.46	2.7663+03	7.3355+04	7.2710+04
3.85	3.8431+03	1.2175+05	9.7017+04
4.23	5.0851+03	1.1246+05	1.0157+05
4.62	6.5982+03	1.3324+05	1.0435+05
5.00	8.2502+03	2.0437+05	1.0725+05
5.38	9.8425+03	1.0700+05	9.4952+04
5.77	1.1879+04	6.5542+04	6.5173+04
6.15	1.3702+04	4.3846+04	4.3757+04
6.54	1.5131+04	4.0268+04	4.0245+04
6.92	1.6513+04	4.2609+04	4.2590+04
7.31	1.8061+04	4.2335+04	4.2316+04
7.69	2.0171+04	4.2871+04	4.2844+04
8.08	2.2837+04	4.9094+04	4.9024+04
8.46	2.5751+04	8.2074+04	8.1725+04
8.85	2.7404+04	5.9398+04	5.9230+04
9.23	2.7728+04	5.8992+04	5.8836+04
9.62	2.7418+04	1.9690+05	8.0345+04
10.00	2.6855+04	4.6786+04	4.6750+04
10.38	2.6276+04	4.4277+04	4.4274+04
10.77	2.5680+04	4.8111+04	4.8111+04
11.15	2.4932+04	4.4551+04	4.4551+04
11.54	2.4220+04	1.0846+05	1.0846+05
11.92	2.3610+04	3.0890+04	3.0888+04
12.31	2.3099+04	3.3050+04	3.3010+04
12.69	2.2625+04	2.7057+04	2.7049+04
13.08	2.2767+04	2.8927+04	2.8895+04
13.46	2.1757+04	4.5723+04	4.1144+04
13.85	2.1071+04	3.2721+04	3.2651+04
14.23	2.0149+04	3.4771+04	3.4648+04
14.62	1.9305+04	3.9836+04	3.9683+04
15.00	1.8528+04	3.9310+04	3.9139+04
15.38	1.7813+04	3.5747+04	3.5607+04
15.77	1.7128+04	3.1274+04	3.1189+04
16.15	1.6451+04	2.9682+04	2.9611+04
16.54	1.5751+04	2.7131+04	2.7062+04
16.92	1.5092+04	2.5444+04	2.5374+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
8.0310+03	6.6343+04	4.2147+03	4.4836+04

1.1090-02 3.7572-03 3518 224 191 33

TABLE 17 (sheet 22 of 57)

THETA= 1.3787+00 EV = 2.8756+04 DEG R = 1.6000+04 DEG K

GAMMA= 3.7600+02

PRESSURE= 1.0167+08 (DYNE/CM2) = 1.0034+02 (ATM)

RHO= 1.0304-02 (G/CM3) = 6.4328-01 (LB/FT3)

ZBAR= 9.9418-01

UMAX	DELTA U
18.00	.63

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.63	2.8821+04	5.8548+04	5.8530+04
1.25	4.1066+03	3.0634+04	2.0353+04
1.88	1.5070+03	1.7803+04	1.7744+04
2.50	1.0263+03	4.3804+04	4.3612+04
3.13	1.3334+03	9.6787+04	9.6445+04
3.75	1.8444+03	1.0625+05	1.0766+05
4.38	2.4317+03	3.1178+04	3.0974+04
5.00	3.0951+03	2.4855+04	2.4758+04
5.63	3.9488+03	2.1128+04	2.1075+04
6.25	5.4183+03	3.1839+04	3.2836+04
6.88	7.5749+03	4.0842+04	3.9311+04
7.50	8.9696+03	5.6217+04	5.7943+04
8.13	9.9158+03	1.8346+04	1.8331+04
8.75	1.0641+04	2.0553+04	2.0529+04
9.38	1.0770+04	2.1065+04	2.1027+04
10.00	1.0793+04	3.7249+04	3.7436+04
10.63	1.1120+04	6.6243+04	6.4878+04
11.25	1.0261+04	3.0605+04	3.0506+04
11.88	9.7792+03	5.3656+04	5.3377+04
12.50	9.1693+03	6.3393+04	6.1770+04
13.13	8.6341+03	6.9159+04	6.8293+04
13.75	8.1489+03	8.8422+04	8.3092+04
14.38	7.6991+03	1.1891+05	1.1070+05
15.00	7.3571+03	1.4030+05	1.3098+05
15.63	7.2021+03	1.3567+05	1.2747+05
16.25	7.3074+03	1.1206+05	1.0879+05
16.87	7.5544+03	8.1689+04	7.9806+04
17.50	7.8537+03	5.3145+04	5.2288+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
3.4291+03	4.6817+04	2.2277+03	3.1173+04

6.1130-04	3.9062-03	5119	399	320	79

TABLE 17 (sheet 23 of 57)

THETA= 1.3787+00 EV = 2.8756+04 DEG R = 1.6000+04 DEG K

GAMMA= 1.9700+02

PRESSURE= 2.0200+08 (DYNE/CM2) = 1.9936+02 (ATM)

RHO= 2.2538-02 (G/CM3) = 1.4071+00 (LB/FT3)

ZBAR= 8.6751-01

UMAX	DELTA U
17.00	.63

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.63	4.6467+04	7.6468+04	7.6450+04
1.25	6.5497+03	3.2836+04	2.3464+04
1.88	2.0836+03	1.9568+04	1.9493+04
2.50	1.3950+03	4.6937+04	4.6696+04
3.13	1.6921+03	1.0368+05	9.4077+04
3.75	2.0115+03	1.1461+05	1.0087+05
4.38	3.5039+03	3.6268+04	3.6138+04
5.00	4.4845+03	2.6887+04	2.6802+04
5.63	5.7021+03	2.4694+04	2.4622+04
6.25	7.6713+03	3.8069+04	3.7952+04
6.88	1.0252+04	5.4355+04	5.7542+04
7.50	1.1664+04	7.6171+04	6.0781+04
8.13	1.2542+04	2.2262+04	2.2052+04
8.75	1.3165+04	2.4278+04	2.4263+04
9.38	1.3174+04	2.3950+04	2.3921+04
10.00	1.3109+04	3.6722+04	3.6548+04
10.63	1.3403+04	6.1816+04	5.0829+04
11.25	1.2361+04	2.9838+04	2.9759+04
11.88	1.1741+04	4.9945+04	4.9766+04
12.50	1.0980+04	6.0645+04	6.0175+04
13.13	1.0314+04	6.6290+04	6.6008+04
13.75	9.6912+03	8.7953+04	8.2110+04
14.38	9.0876+03	1.2298+05	1.1373+05
15.00	8.5792+03	1.4775+05	1.3774+05
15.63	8.2364+03	1.4227+05	1.3353+05
16.25	8.1325+03	1.1439+05	1.1129+05
16.87	8.1731+03	7.9355+04	7.8196+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
4.9121+03	5.1882+04	3.1269+03	3.5043+04

8.0029-04 3.9840-03 4143 370 301 69

TABLE 17 (sheet 24 of 57)

THETA= 1.3787+00 EV = 2.8756+04 DEG R = 1.6000+04 DEG K

GAMMA= 8.3000+01

PRESSURE= 5.0522+08 (DYNE/CM2) = 4.9862+02 (ATM)

RHO= 6.3510-02 (G/CM3) = 3.9649+00 (LB/FT3)

ZBAR= 7.3071-01

UMAX	DELTA U
16.00	.63

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.63	9.0117+04	1.0606+05	1.0605+05
1.25	1.1312+04	3.6451+04	3.3707+04
1.88	3.6034+03	2.2378+04	2.2278+04
2.50	2.1556+03	5.1083+04	5.0879+04
3.13	2.9042+03	1.1311+05	8.4596+04
3.75	3.9206+03	1.2643+05	8.8653+04
4.38	5.3047+03	4.4221+04	4.4005+04
5.00	6.7986+03	3.0207+04	3.0133+04
5.63	8.5954+03	2.8657+04	2.8607+04
6.25	1.1344+04	3.9876+04	3.9744+04
6.88	1.4517+04	5.5017+04	5.4831+04
7.50	1.5797+04	7.4498+04	5.8260+04
8.13	1.6400+04	2.5181+04	2.5170+04
8.75	1.6703+04	2.6617+04	2.6609+04
9.38	1.6389+04	2.5861+04	2.5845+04
10.00	1.6063+04	3.6414+04	3.6318+04
10.63	1.6086+04	5.7573+04	5.0233+04
11.25	1.4842+04	3.0420+04	3.0362+04
11.88	1.3968+04	4.7966+04	4.7949+04
12.50	1.3008+04	5.8794+04	5.8533+04
13.13	1.2165+04	6.4482+04	6.4142+04
13.75	1.1347+04	8.7080+04	8.4397+04
14.38	1.0506+04	1.1778+05	1.0857+05
15.00	9.7345+03	1.2679+05	1.1630+05
15.63	9.0489+03	9.6978+04	9.0795+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
7.7794+03	5.7485+04	4.8040+03	3.8883+04

8.4231-04	4.1656-03	2810	286	235	51

TABLE 17 (sheet 25 of 57)

THETA= 1.3787+00 EV = 2.8756+04 DEG R = 1.6000+04 DEG K

GAMMA= 4.3000+01

PRESSURE= 1.0090+09 (DYNE/CM2) = 9.9581+02 (ATM)

RHO= 1.3995-01 (G/CM3) = 8.7371+00 (LB/FT3)

ZBAR= 6.4006-01

UMAX	DELTA U
16.00	.63

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.63	1.5352+05	1.6680+05	1.6679+05
1.25	1.9250+04	4.4026+04	4.4013+04
1.88	6.0195+03	2.6005+04	2.5974+04
2.50	3.3349+03	5.3717+04	5.3481+04
3.13	3.9188+03	1.1718+05	7.9729+04
3.75	5.0627+03	1.3382+05	7.9156+04
4.38	6.7305+03	5.0277+04	5.0094+04
5.00	8.5662+03	3.3058+04	3.3008+04
5.63	1.0769+04	3.2271+04	3.2233+04
6.25	1.3994+04	4.3899+04	4.3747+04
6.88	1.7651+04	6.0430+04	6.0236+04
7.50	1.6845+04	8.0910+04	5.9573+04
8.13	1.9278+04	2.8072+04	2.8070+04
8.75	1.9378+04	2.9081+04	2.9081+04
9.38	1.8867+04	2.7873+04	2.7872+04
10.00	1.8383+04	3.5644+04	3.5584+04
10.63	1.8260+04	5.3398+04	4.9709+04
11.25	1.6877+04	3.2349+04	3.2271+04
11.88	1.5849+04	4.9198+04	4.8976+04
12.50	1.4764+04	5.9196+04	5.8903+04
13.13	1.3811+04	6.6485+04	6.6232+04
13.75	1.2875+04	9.2661+04	9.1780+04
14.38	1.1912+04	1.2775+05	1.1674+05
15.00	1.1047+04	1.3884+05	1.2446+05
15.63	1.0299+04	1.0699+05	9.9303+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.1117+04	6.2773+04	6.6017+03	4.2525+04

5.4073-04	3.8957-03	2624	268	225	43

TABLE 17 (sheet 26 of 57)

THETA= 1.7234+00 EV = 3.5945+04 DEG R = 2.0000+04 DEG K

GAMMA= 5.6600+02

PRESSURE= 1.0151+08 (DYNE/CM2) = 1.0018+02 (ATM)

RHO= 6.7550-03 (G/CM3) = 4.2172-01 (LB/FT3)

ZBAR= 1.4080+00

UMAX	DELTA U
18.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	4.1564+04	7.6178+04	7.6166+04
1.00	5.3970+03	3.4911+04	2.3757+04
1.50	1.9580+03	1.4623+04	1.4569+04
2.00	1.0911+03	2.7897+04	2.7783+04
2.50	8.1758+02	5.3898+04	5.0280+04
3.00	8.7288+02	5.7326+04	5.3554+04
3.50	8.8646+02	2.4692+04	2.4571+04
4.00	9.4899+02	2.6008+04	2.4662+04
4.50	1.2074+03	1.9526+04	1.9412+04
5.00	1.7294+03	3.2693+04	5.7865+04
5.50	2.7814+03	2.4370+04	2.4719+04
6.00	3.7156+03	2.6353+04	2.6677+04
6.50	4.4010+03	1.3169+04	1.3138+04
7.00	4.9834+03	1.5282+04	1.5236+04
7.50	5.2367+03	1.7783+04	1.7733+04
8.00	5.3615+03	4.0526+04	4.1991+04
8.50	5.5614+03	8.3243+04	1.3482+05
9.00	5.2669+03	5.3270+04	5.2920+04
9.50	5.0823+03	8.5551+04	8.4087+04
10.00	4.8530+03	8.7337+04	8.3937+04
10.50	4.6080+03	9.8045+04	9.4719+04
11.00	4.3794+03	1.0789+05	1.0001+05
11.50	4.1957+03	1.1195+05	1.0412+05
12.00	4.1638+03	1.0661+05	9.9190+04
12.50	4.4169+03	9.1669+04	8.6707+04
13.00	5.0587+03	7.3985+04	7.1889+04
13.50	5.9416+03	5.6526+04	5.5714+04
14.00	6.9622+03	4.0998+04	4.0518+04
14.50	7.2669+03	2.7448+04	2.7334+04
15.00	7.5373+03	1.8800+04	1.8736+04
15.50	7.7087+03	1.5566+04	1.5532+04
16.00	7.7235+03	2.2182+04	2.3011+04
16.50	7.7255+03	2.9833+04	2.9406+04
17.00	7.7517+03	4.7825+04	4.6910+04
17.50	7.7961+03	3.8320+04	3.7001+04
18.00	8.2768+03	3.7587+04	3.5294+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
2.2246+03	3.0960+04	1.4143+03	2.5311+04

3.5424-03	3.4039-03	9364	685	585	100

TABLE 17 (sheet 27 of 57)

THETA= 1.7234+00 EV = 3.5945+04 DEG R = 2.0000+04 DEG K

GAMMA= 2.8600+02

PRESSURE= 2.0292+08 (DYNE/CM2) = 2.0027+02 (ATM)

RHO= 1.4707-02 (G/CM3) = 9.1813-01 (LB/FT3)

ZBAR= 1.2798+00

UMAX	DELTA U
17.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	7.0633+04	1.1150+05	1.1149+05
1.00	9.2185+03	4.2633+04	2.6695+04
1.50	3.1708+03	1.7228+04	1.7154+04
2.00	1.6928+03	3.2780+04	3.2590+04
2.50	1.3328+03	6.2877+04	5.8493+04
3.00	1.4011+03	6.1147+04	6.0998+04
3.50	1.4748+03	2.6450+04	2.6347+04
4.00	1.6717+03	2.7465+04	2.8134+04
4.50	2.0227+03	2.0410+04	2.0319+04
5.00	2.7660+03	3.2801+04	3.8379+04
5.50	4.0959+03	2.9048+04	2.9146+04
6.00	5.1879+03	3.2236+04	2.8842+04
6.50	5.9722+03	1.5430+04	1.5398+04
7.00	6.6203+03	1.7631+04	1.7596+04
7.50	6.8779+03	1.9387+04	1.9341+04
8.00	6.9905+03	4.2556+04	4.2017+04
8.50	7.1882+03	8.4027+04	7.6734+04
9.00	6.7785+03	4.5074+04	4.4894+04
9.50	6.4998+03	7.3524+04	9.0298+04
10.00	6.1674+03	7.6107+04	7.5496+04
10.50	5.8330+03	8.6611+04	8.4397+04
11.00	5.5202+03	9.8060+04	8.9017+04
11.50	5.2549+03	1.0644+05	9.7206+04
12.00	5.1393+03	1.0724+05	9.7844+04
12.50	5.2987+03	9.6845+04	9.1448+04
13.00	5.8359+03	8.0622+04	7.8837+04
13.50	6.6060+03	6.2431+04	6.2050+04
14.00	7.5098+03	4.5372+04	4.5066+04
14.50	7.4497+03	3.0353+04	3.0245+04
15.00	7.9602+03	2.0439+04	2.0372+04
15.50	8.0870+03	1.5442+04	1.5393+04
16.00	8.0765+03	1.8383+04	1.8368+04
16.50	8.0575+03	2.1527+04	2.1447+04
17.00	8.0663+03	3.0434+04	3.0298+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM3/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
3.4190+03	3.4423+04	2.2576+03	2.7548+04

4.2601-03 3.8477-03 6262 468 383 85

TABLE 17 (sheet 28 of 57)

THETA= 1.7234+00 EV = 3.5945+04 DEG R = 2.0000+04 DEG K

GAMMA= 1.1300+02

PRESSURE= 5.0846+08 (DYNE/CM2) = 5.0181+02 (ATM)

RHO= 4.1590-02 (G/CM3) = 2.5964+00 (LB/FT3)

ZBAR= 1.1454+00

UMAX	DELTA U
16.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	1.5275+05	1.7250+05	1.7249+05
1.00	1.9122+04	5.4990+04	4.2056+04
1.50	5.8094+03	2.2200+04	2.2167+04
2.00	2.7735+03	4.0766+04	4.0584+04
2.50	2.3628+03	7.7413+04	5.8025+04
3.00	2.4042+03	7.4812+04	5.6231+04
3.50	2.6716+03	3.1440+04	3.1278+04
4.00	3.1133+03	2.9197+04	2.9115+04
4.50	3.7756+03	2.2906+04	2.2854+04
5.00	4.9772+03	3.4082+04	3.3947+04
5.50	6.7589+03	3.3495+04	3.3293+04
6.00	8.0104+03	3.7383+04	3.5126+04
6.50	8.8444+03	1.8533+04	1.8515+04
7.00	9.4898+03	2.0514+04	2.0494+04
7.50	9.6623+03	2.1504+04	2.1437+04
8.00	9.6851+03	4.2675+04	4.2460+04
8.50	9.8029+03	8.0047+04	6.0918+04
9.00	9.2035+03	4.1718+04	4.1565+04
9.50	8.7495+03	6.6949+04	7.1008+04
10.00	8.2452+03	7.3078+04	7.2679+04
10.50	7.7582+03	8.1571+04	7.9743+04
11.00	7.2905+03	9.4425+04	8.4676+04
11.50	6.8662+03	1.0916+05	9.6404+04
12.00	6.5883+03	1.1731+05	1.0404+05
12.50	6.5715+03	1.1131+05	1.0121+05
13.00	6.9093+03	9.5424+04	9.1133+04
13.50	7.4696+03	7.4647+04	7.2833+04
14.00	8.1635+03	5.3697+04	5.3342+04
14.50	8.2810+03	3.5032+04	3.4800+04
15.00	8.3813+03	2.2403+04	2.2343+04
15.50	8.4249+03	1.5088+04	1.5059+04
16.00	8.3534+03	1.3056+04	1.3048+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
8.0807+03	4.0602+04	3.9116+03	3.0811+04

4.0547-03	4.3309-03	4293	349	280	69

TABLE 17 (sheet 29 of 57)

THETA= 1.7234+00 EV = 3.5945+04 DEG R = 2.0000+04 DEG K

GAMMA= 5.5000+01

PRESSURE= 1.0202+09 (DYNE/CM2) = 1.0068+03 (ATM)

RHO= 9.3961-02 (G/CM3) = 5.8660+00 (LB/FT3)

ZBAR= 1.0416+00

UMAX	DELTA U
16.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	2.8407+05	2.9719+05	2.9718+05
1.00	3.5553+04	7.2612+04	7.2595+04
1.50	1.0757+04	2.8778+04	2.8723+04
2.00	5.0337+03	4.6688+04	4.6346+04
2.50	3.9176+03	8.5923+04	5.4804+04
3.00	3.8138+03	8.4323+04	5.3242+04
3.50	4.1403+03	3.6504+04	3.6409+04
4.00	4.7625+03	3.1917+0	3.1803+04
4.50	5.6934+03	2.6675+04	2.6649+04
5.00	7.2636+03	4.0752+04	4.0545+04
5.50	9.4166+03	4.5604+04	4.5469+04
6.00	1.0745+04	5.2113+04	4.6197+04
6.50	1.1582+04	2.3041+04	2.3010+04
7.00	1.2194+04	2.4638+04	2.4593+04
7.50	1.2292+04	2.4282+04	2.4229+04
8.00	1.2248+04	4.1217+04	4.1031+04
8.50	1.2325+04	7.3644+04	5.8671+04
9.00	1.1554+04	4.2159+04	4.2008+04
9.50	1.0959+04	6.6551+04	6.6109+04
10.00	1.0306+04	7.3428+04	7.3099+04
10.50	9.6863+03	8.1505+04	8.0888+04
11.00	9.0798+03	9.5750+04	9.3307+04
11.50	8.5187+03	1.1460+05	1.0522+05
12.00	8.1056+03	1.2640+05	1.1510+05
12.50	7.9444+03	1.2141+05	1.1109+05
13.00	8.1147+03	1.0403+05	9.7807+04
13.50	8.4927+03	8.0700+04	7.8271+04
14.00	9.0050+03	5.7410+04	5.7015+04
14.50	9.0220+03	3.7231+04	3.7001+04
15.00	9.0388+03	2.3604+04	2.3500+04
15.50	9.0228+03	1.5902+04	1.5856+04
16.00	8.9183+03	1.3485+04	1.3452+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
9.7963+03	4.7852+04	6.0114+03	3.5825+04

2.5350-03	4.0888-03	3945	325	267	58

TABLE 17 (sheet 30 of 57)

THETA= 2.1542+00 EV = 4.4931+04 DEG R = 2.5000+04 DEG K

GAMMA= 9.2600+02

PRESSURE= 1.0116+08 (DYNE/CM2) = 9.9840+01 (ATM)

RHO= 4.5895-03 (G/CM3) = 2.8652-01 (LB/FT3)

ZBAR= 1.7702+00

UMAX	DELTA U
18.00	.40

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.40	4.6997+04	7.9973+04	7.9960+04
.80	5.9296+03	3.0834+04	2.4142+04
1.20	2.0971+03	1.3027+04	1.2971+04
1.60	1.0962+03	1.5424+04	1.5314+04
2.00	6.3799+02	2.9297+04	2.7550+04
2.40	5.7151+02	3.1806+04	3.2739+04
2.80	4.6800+02	2.3468+04	2.2987+04
3.20	4.4019+02	3.0212+04	3.0025+04
3.60	4.8422+02	1.9404+04	1.9244+04
4.00	6.5055+02	3.1891+04	3.2161+04
4.40	1.0258+03	1.3997+04	1.3901+04
4.80	1.4319+03	1.3011+04	1.3159+04
5.20	1.6601+03	9.3840+03	9.3244+03
5.60	1.8995+03	1.1070+04	1.1032+04
6.00	2.0043+03	1.5641+04	1.5553+04
6.40	2.0503+03	3.6325+04	6.5365+04
6.80	2.1375+03	7.9939+04	8.0138+04
7.20	2.1224+03	7.2467+04	7.0584+04
7.60	2.1164+03	1.0351+05	1.2896+05
8.00	2.1104+03	1.0770+05	1.0514+05
8.40	2.0448+03	1.2088+05	1.1299+05
8.80	1.9638+03	1.1777+05	1.0559+05
9.20	1.9138+03	1.1004+05	9.9472+04
9.60	2.0223+03	9.2737+04	8.4041+04
10.00	2.4414+03	7.1823+04	6.6493+04
10.40	3.2516+03	5.3873+04	5.0976+04
10.80	4.3063+03	3.9865+04	3.8660+04
11.20	5.4932+03	2.8362+04	2.8029+04
11.60	5.8852+03	1.9367+04	1.9283+04
12.00	6.4258+03	1.4477+04	1.4447+04
12.40	6.4339+03	1.4486+04	1.4443+04
12.80	6.4076+03	2.5828+04	2.4234+04
13.20	6.3670+03	3.6895+04	3.5409+04
13.60	6.3679+03	5.8537+04	7.4138+04
14.00	6.4269+03	5.7851+04	5.4428+04
14.40	6.6278+03	6.5887+04	6.1261+04
14.80	6.6740+03	7.0928+04	6.5700+04
15.20	7.2712+03	7.0836+04	6.5963+04
15.60	7.6991+03	6.3500+04	5.8900+04
16.00	8.2656+03	4.5702+04	4.3336+04
16.40	9.0365+03	2.9761+04	2.8930+04
16.80	9.9996+03	2.1441+04	2.1323+04
17.20	1.0978+04	1.9606+04	1.9573+04
17.60	1.1708+04	2.2271+04	2.1704+04
18.00	1.2335+04	2.2471+04	2.1422+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.3136+03	2.7248+04	8.6913+02	1.9903+04

8.9830-04 3.3692-03 13980 944 809 135

TABLE 17 (sheet 31 of 57)

THETA= 2.1542+00 EV = 4.4931+04 DEG R = 2.5000+04 DEG K

GAMMA= 4.6200+02

PRESSURE= 2.0243+08 (DYNE/CM2) = 1.9978+02 (ATM)

RHO= 9.8745-03 (G/CM3) = 6.1646-01 (LB/FT3)

ZBAR= 1.6491+00

UMAX	DELTA U
17.00	.40

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.40	8.3408+04	1.2441+05	1.2440+05
.80	1.0552+04	4.1759+04	2.9829+04
1.20	3.5348+03	1.5883+04	1.5821+04
1.60	1.7795+03	1.9986+04	1.9909+04
2.00	1.0652+03	3.6582+04	3.3569+04
2.40	9.2278+02	3.7039+04	3.5053+04
2.80	7.8754+02	2.4761+04	2.4570+04
3.20	7.3843+02	3.0229+04	3.0193+04
3.60	8.0952+02	1.9830+04	1.9750+04
4.00	1.0689+03	3.1732+04	3.2136+04
4.40	1.6434+03	1.6035+04	1.5953+04
4.80	2.2077+03	1.4936+04	1.4846+04
5.20	2.5586+03	1.0803+04	1.0755+04
5.60	2.8950+03	1.2693+04	1.2658+04
6.00	3.0494+03	1.7022+04	1.6950+04
6.40	3.1140+03	3.9850+04	6.5982+04
6.80	3.2154+03	8.4837+04	1.4044+05
7.20	3.1402+03	6.7938+04	6.7493+04
7.60	3.0771+03	9.6549+04	1.2103+05
8.00	3.0082+03	1.0160+05	9.4328+04
8.40	2.6840+03	1.1158+05	1.0023+05
8.80	2.7512+03	1.1233+05	1.0210+05
9.20	2.6546+03	1.0653+05	9.7935+04
9.60	2.7213+03	9.2238+04	8.5612+04
10.00	3.1033+03	7.4013+04	6.9999+04
10.40	3.8867+03	5.8091+04	5.6732+04
10.80	4.9180+03	4.4944+04	4.4301+04
11.20	6.0823+03	3.3071+04	3.2919+04
11.60	6.4518+03	2.2808+04	2.2713+04
12.00	6.7690+03	1.6796+04	1.6761+04
12.40	6.9598+03	1.5528+04	1.5472+04
12.80	6.9170+03	2.5111+04	2.5009+04
13.20	6.8627+03	3.5083+04	3.4691+04
13.60	6.6526+03	5.5076+04	5.4732+04
14.00	6.9021+03	5.3772+04	5.2495+04
14.40	7.1775+03	6.1949+04	5.8644+04
14.80	7.3576+03	6.6782+04	6.3425+04
15.20	7.7550+03	6.7389+04	6.4549+04
15.60	8.1356+03	6.1669+04	5.8416+04
16.00	8.6278+03	4.6020+04	4.4672+04
16.40	9.2733+03	3.1285+04	3.1024+04
16.80	9.9210+03	2.2160+04	2.2073+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
2.0984+03	2.9204+04	1.3984+03	2.2230+04

1.0615-03 3.5242-03 11540 703 584 119

TABLE 17 (sheet 32 of 57)

THETA= 2.1542+00 EV = 4.4931+04 DEG R = 2.5000+04 DEG K

GAMMA= 1.8200+02

PRESSURE= 5.0812+08 (DYNE/CM2) = 5.0148+02 (ATM)

RHO= 2.7723-02 (G/CM3) = 1.7307+00 (LB/FT3)

ZBAR= 1.4910+00

UMAX	DELTA U
17.00	.40

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.40	1.8065+05	2.2469+05	2.2357+05
.80	2.2591+04	6.1269+04	4.5899+04
1.20	6.7565+03	2.1263+04	2.1213+04
1.60	3.2421+03	2.7623+04	2.7444+04
2.00	1.9900+03	4.8322+04	3.6130+04
2.40	1.6583+03	4.5715+04	3.6892+04
2.80	1.4508+03	2.7325+04	2.7224+04
3.20	1.4257+03	3.0608+04	3.0481+04
3.60	1.5795+03	2.1297+04	2.1223+04
4.00	2.0387+03	3.3723+04	3.0463+04
4.40	2.9533+03	2.2987+04	2.2862+04
4.80	3.7730+03	2.2451+04	2.2348+04
5.20	4.3179+03	1.4362+04	1.4336+04
5.60	4.8059+03	1.6279+04	1.6215+04
6.00	5.0393+03	1.9120+04	1.9048+04
6.40	5.1347+03	4.2787+04	4.2568+04
6.80	5.2626+03	8.7162+04	6.8266+04
7.20	5.0701+03	6.1414+04	6.0966+04
7.60	4.8990+03	8.7118+04	7.5915+04
8.00	4.7069+03	9.3941+04	8.6884+04
8.40	4.4672+03	1.0158+05	9.5414+04
8.80	4.2272+03	1.0497+05	9.2880+04
9.20	4.0291+03	1.0299+05	9.2719+04
9.60	3.9947+03	9.4307+04	8.4619+04
10.00	4.2687+03	8.0821+04	7.5854+04
10.40	4.9426+03	6.7360+04	6.5077+04
10.80	5.8591+03	5.4005+04	5.3624+04
11.20	6.9075+03	4.0864+04	4.0655+04
11.60	7.2030+03	2.8351+04	2.8212+04
12.00	7.4514+03	1.9974+04	1.9884+04
12.40	7.5909+03	1.6985+04	1.6938+04
12.80	7.5125+03	2.4102+04	2.4036+04
13.20	7.4292+03	3.2695+04	3.2497+04
13.60	7.3942+03	5.0181+04	5.3832+04
14.00	7.4209+03	4.8825+04	4.8539+04
14.40	7.9479+03	5.6593+04	5.5523+04
14.80	7.9513+03	6.1340+04	5.9504+04
15.20	8.4132+03	6.3476+04	6.1519+04
15.60	8.7444+03	6.0479+04	5.7171+04
16.00	9.1823+03	4.8090+04	4.7182+04
16.40	9.7537+03	3.5073+04	3.4872+04
16.80	1.0331+04	2.5629+04	2.5549+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
3.8537+03	3.3382+04	2.5324+03	2.6203+04

1.1698-02 4.0714-03 8596 558 457 101

TABLE 17 (sheet 33 of 57)

THETA= 2.1542+00 EV = 4.4931+04 DEG R = 2.5000+04 DEG K

GAMMA= 8.8000+01

PRESSURE= 1.0178+09 (DYNE/CM2) = 1.0045+03 (ATM)

RHO= 6.0956-02 (G/CM3) = 3.8055+00 (LB/FT3)

ZBAR= 1.4025+00

UMAX	DELTA U
16.00	.40

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.40	3.4220+05	3.6706+05	3.6664+05
.80	4.2797+04	8.6950+04	8.6946+04
1.20	1.2786+04	2.9301+04	2.9278+04
1.60	5.6103+03	3.5756+04	3.5545+04
2.00	3.5476+03	6.0006+04	3.9399+04
2.40	2.7481+03	5.5069+04	3.8018+04
2.80	2.4436+03	3.0957+04	3.0832+04
3.20	2.4339+03	3.2344+04	3.2149+04
3.60	2.6905+03	2.3152+04	2.3100+04
4.00	3.3615+03	3.5165+04	3.5038+04
4.40	4.5888+03	2.6462+04	2.6394+04
4.80	5.5913+03	2.6138+04	2.6020+04
5.20	6.2486+03	1.6760+04	1.6739+04
5.60	6.8108+03	1.8540+04	1.8508+04
6.00	7.0533+03	2.0759+04	2.0719+04
6.40	7.1276+03	4.2991+04	4.2787+04
6.80	7.2324+03	8.4719+04	6.6332+04
7.20	6.9258+03	5.9125+04	5.8867+04
7.60	6.6450+03	8.4362+04	8.3910+04
8.00	6.3403+03	9.2634+04	8.8529+04
8.40	5.9961+03	9.9616+04	9.4592+04
8.80	5.6530+03	1.0376+05	9.2793+04
9.20	5.3562+03	1.0516+05	9.5680+04
9.60	5.2213+03	1.0085+05	9.2971+04
10.00	5.3850+03	9.0567+04	8.5559+04
10.40	5.9373+03	7.8066+04	7.4951+04
10.80	6.7220+03	6.3599+04	6.1404+04
11.20	7.6383+03	4.8208+04	4.7907+04
11.60	7.8570+03	3.3288+04	3.3101+04
12.00	8.0388+03	2.2926+04	2.2823+04
12.40	8.1301+03	1.8483+04	1.8445+04
12.80	8.0241+03	2.4154+04	2.4049+04
13.20	7.9203+03	3.2435+04	3.2314+04
13.60	7.8680+03	4.8666+04	4.6913+04
14.00	7.8790+03	4.7444+04	4.7226+04
14.40	8.8464+03	5.5069+04	5.3686+04
14.80	8.5748+03	5.9712+04	5.7385+04
15.20	9.1530+03	6.2774+04	5.9287+04
15.60	9.3714+03	6.0498+04	5.5302+04
16.00	9.6460+03	4.7511+04	4.6033+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
8.3612+03	3.7816+04	4.0419+03	2.9567+04

1.2825-02 4.0998-03 7129 483 395 88

EXIT CALLED FROM 024251

TABLE 17 (sheet 34 of 57)

THETA= 2.5850+00 EV = 5.3917+04 DEG R = 3.0000+04 DEG K

GAMMA= 1.3930+03

PRESSURE= 1.0111+08 (DYNE/CM2) = 9.9790+01 (ATM)

RHO= 3.3575-03 (G/CM3) = 2.0961-01 (LB/FT3)

ZBAR= 2.1144+00

UMAX	DELTA U
19.00	.33

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.33	5.2376+04	8.9736+04	8.7829+04
.67	6.8257+03	2.9260+04	2.[illegible]900+04
1.00	2.3627+03	1.3981+04	1.3903+04
1.33	1.2235+03	1.1377+04	1.1298+04
1.67	6.5337+02	2.1098+04	1.9793+04
2.00	5.4537+02	2.4507+04	2.3669+04
2.33	4.5646+02	2.0764+04	1.9883+04
2.67	3.4434+02	2.5623+04	2.5256+04
3.00	3.4118+02	1.8324+04	1.9074+04
3.33	3.8535+02	2.6313+04	2.6436+04
3.67	4.7927+02	1.1867+04	1.1771+04
4.00	6.7913+02	1.4906+04	1.4713+04
4.33	7.0781+02	8.6972+03	8.5028+03
4.67	8.0592+02	9.2804+03	9.1320+03
5.00	8.4569+02	1.2966+04	1.2816+04
5.33	8.2927+02	2.6395+04	3.2763+04
5.67	8.7719+02	5.7771+04	5.7441+04
6.00	9.2949+02	6.9778+04	7.1843+04
6.33	9.7865+02	9.4614+04	8.2884+04
6.67	1.0315+03	1.1345+05	9.8024+04
7.00	1.0266+03	1.3254+05	1.2673+05
7.33	9.9589+02	1.0430+05	9.4235+04
7.67	9.8135+02	9.8446+04	8.7465+04
8.00	1.0789+03	8.8011+04	7.6898+04
8.33	1.4048+03	7.5178+04	6.5584+04
8.67	2.0108+03	6.0092+04	5.1790+04
9.00	2.7952+03	4.3609+04	3.8746+04
9.33	3.6818+03	2.7959+04	2.5927+04
9.67	3.9945+03	1.6812+04	1.6604+04
10.00	4.2706+03	1.1950+04	1.1931+04
10.33	4.4443+03	1.2690+04	1.2629+04
10.67	4.4076+03	2.3206+04	2.4172+04
11.00	4.3530+03	3.5331+04	3.3575+04
11.33	4.3311+03	5.2973+04	4.7238+04
11.67	4.3641+03	6.0308+04	6.2223+04
12.00	4.5007+03	6.0849+04	5.6555+04
12.33	4.7678+03	6.5514+04	5.9928+04
12.67	5.1535+03	6.6485+04	6.0666+04
13.00	5.5559+03	6.0490+04	5.4618+04
13.33	6.1387+03	4.3514+04	3.8886+04
13.67	6.9279+03	2.6843+04	2.4324+04
14.00	7.8356+03	1.7688+04	1.6958+04
14.33	8.6979+03	1.5747+04	1.5683+04
14.67	9.4788+03	1.7509+04	1.7271+04
15.00	1.0126+04	1.7593+04	1.7278+04
15.33	1.0565+04	1.6039+04	1.6015+04
15.67	1.0902+04	1.5835+04	1.5819+04
16.00	1.1201+04	1.7016+04	1.6998+04
16.33	1.1626+04	2.1230+04	2.0962+04
16.67	1.2494+04	2.4859+04	2.4069+04
17.00	1.3612+04	2.1572+04	2.1250+04
17.33	1.4417+04	1.7275+04	1.7262+04
17.67	1.5094+04	1.8050+04	1.8038+04
18.00	1.5528+04	2.1050+04	2.0717+04
18.33	1.5750+04	2.0353+04	2.0006+04
18.67	1.5950+04	1.8785+04	1.8725+04
19.00	1.6164+04	1.8048+04	1.8046+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
8.9015+02	2.8636+04	6.3318+02	1.8710+04

8.7446-03	3.9050-03	17007	957	798	159

TABLE 17 (sheet 35 of 57)

THETA= 2.5850+00 EV = 5.3917+04 DEG R = 3.0000+04 DEG K

GAMMA= 6.9300+02

PRESSURE= 2.0321+08 (DYNE/CM2) = 2.0056+02 (ATM)

RHO= 7.2491-03 (G/CM3) = 4.5256-01 (LB/FT3)

ZBAR= 1.9686+00

UMAX	DELTA U
18.00	.33

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.33	9.2316+04	1.3269+05	1.3267+05
.67	1.1550+04	3.9360+04	3.2342+04
1.00	3.6829+03	1.6591+04	1.6525+04
1.33	1.8360+03	1.4156+04	1.4111+04
1.67	9.9152+02	2.5761+04	2.3642+04
2.00	7.7025+02	2.8277+04	2.7145+04
2.33	6.2516+02	2.2793+04	2.2377+04
2.67	4.8338+02	2.7806+04	3.4694+04
3.00	4.7728+02	1.9080+04	1.3974+04
3.33	5.5652+02	2.8417+04	4.5599+04
3.67	7.5112+02	1.3227+04	1.3116+04
4.00	1.0477+03	1.4493+04	1.7906+04
4.33	1.1436+03	9.6607+03	9.6096+03
4.67	1.3042+03	1.0691+04	1.0639+04
5.00	1.3606+03	1.4824+04	1.4720+04
5.33	1.3800+03	3.1257+04	3.1061+04
5.67	1.4441+03	6.7235+04	6.7958+04
6.00	1.4800+03	7.2804+04	7.2653+04
6.33	1.5090+03	9.6011+04	8.5724+04
6.67	1.5410+03	1.1290+05	9.7651+04
7.00	1.5086+03	1.2332+05	1.1652+05
7.33	1.4523+03	1.0532+05	9.5738+04
7.67	1.4171+03	9.7675+04	8.9700+04
8.00	1.5111+03	8.4607+04	7.7091+04
8.33	1.4643+03	7.0134+04	6.5487+04
8.67	2.5381+03	5.6503+04	5.2657+04
9.00	3.4144+03	4.3162+04	4.0546+04
9.33	4.4047+03	2.9756+04	2.8916+04
9.67	4.7476+03	1.9097+04	1.9006+04
10.00	5.0485+03	1.3793+04	1.3748+04
10.33	5.2370+03	1.3979+04	1.3953+04
10.67	5.1881+03	2.4366+04	2.4176+04
11.00	5.1196+03	3.5655+04	3.5052+04
11.33	5.0866+03	5.3369+04	4.7425+04
11.67	5.1076+03	5.7612+04	5.5061+04
12.00	5.2331+03	6.0781+04	5.8419+04
12.33	5.4900+03	6.4670+04	6.1415+04
12.67	5.8655+03	6.4562+04	6.1332+04
13.00	6.2634+03	5.8195+04	5.4761+04
13.33	6.8280+03	4.1993+04	4.0006+04
13.67	7.5961+03	2.6818+04	2.6285+04
14.00	8.5121+03	1.8731+04	1.8671+04
14.33	9.4084+03	1.7077+04	1.7033+04
14.67	1.0158+04	1.9190+04	1.8[illegible]+04
15.00	1.0787+04	1.9773+04	1.9016+04
15.33	1.1197+04	1.7760+04	1.7624+04
15.67	1.1511+04	1.7298+04	1.7170+04
16.00	1.1786+04	1.8290+04	1.8269+04
16.33	1.2207+04	2.2215+04	2.2037+04
16.67	1.3178+04	2.5661+04	2.4707+04
17.00	1.4452+04	2.2292+04	2.1938+04
17.33	1.5312+04	1.8017+04	1.8006+04
17.67	1.6003+04	1.8733+04	1.8723+04
18.00	1.6396+04	2.0630+04	2.0362+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.3621+03	3.0532+04	9.4203+02	2.1570+04

3.4315-03 4.1761-03 13372 724 585 139

TABLE 17 (sheet 36 of 57)

THETA= 2.5850+00 EV = 5.3917+04 DEG R = 3.0000+04 DEG K

GAMMA= 2.7500+02

PRESSURE= 5.0710+08 (DYNE/CM2) = 5.0047+02 (ATM)

RHO= 2.0057-02 (G/CM3) = 1.2522+00 (LB/FT3)

ZBAR= 1.7929+00

UMAX	DELTA U
17.00	.33

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.33	1.9780+05	2.4353+05	2.4150+05
.67	2.4844+04	6.0755+04	4.8572+04
1.00	7.3836+03	2.2095+04	2.2051+04
1.33	3.3726+03	2.0116+04	1.9990+04
1.67	1.8981+03	3.4645+04	2.8060+04
2.00	1.4090+03	3.5036+04	3.0556+04
2.33	1.1223+03	2.5824+04	2.5685+04
2.67	9.4079+02	3.0211+04	2.9517+04
3.00	9.4860+02	2.0575+04	2.0486+04
3.33	1.1279+03	3.0969+04	2.5743+04
3.67	1.5464+03	1.6433+04	1.6371+04
4.00	2.0273+03	1.6365+04	1.6296+04
4.33	2.2587+03	1.1760+04	1.1717+04
4.67	2.5332+03	1.3194+04	1.3139+04
5.00	2.6562+03	1.7398+04	1.7305+04
5.33	2.7001+03	3.7186+04	3.6993+04
5.67	2.7835+03	7.7539+04	6.4602+04
6.00	2.7634+03	7.2599+04	7.2058+04
6.33	2.7302+03	9.4958+04	1.0220+05
6.67	2.6951+03	1.0900+05	9.9626+04
7.00	2.5915+03	1.1524+05	1.0771+05
7.33	2.4690+03	1.0585+05	9.6786+04
7.67	2.3754+03	9.8292+04	9.0906+04
8.00	2.4298+03	8.5147+04	7.8803+04
8.33	2.7732+03	7.0630+04	6.7428+04
8.67	3.4779+03	5.8225+04	5.5618+04
9.00	4.4071+03	4.6631+04	4.4587+04
9.33	5.4620+03	3.4239+04	3.3911+04
9.67	6.8095+03	2.3208+04	2.3123+04
10.00	8.1113+03	1.6913+04	1.6856+04
10.33	8.4966+03	1.6010+04	1.5962+04
10.67	8.2230+03	2.5402+04	2.6253+04
11.00	8.1306+03	3.5680+04	3.5476+04
11.33	8.0780+03	5.2973+04	5.7654+04
11.67	8.0796+03	5.4847+04	5.4365+04
12.00	8.2818+03	5.9866+04	5.8404+04
12.33	8.4673+03	6.3255+04	6.1297+04
12.67	8.8537+03	6.3005+04	6.0844+04
13.00	7.2312+03	5.7377+04	5.4475+04
13.33	7.7576+03	4.2744+04	4.2001+04
13.67	8.4814+03	2.9114+04	2.8980+04
14.00	9.4279+03	2.1713+04	2.1628+04
14.33	1.0421+04	1.9912+04	1.9853+04
14.67	1.1140+04	2.2307+04	2.0802+04
15.00	1.1755+04	2.3106+04	2.0598+04
15.33	1.2120+04	2.0205+04	2.0169+04
15.67	1.2391+04	1.9277+04	1.9273+04
16.00	1.2610+04	1.9812+04	1.9804+04
16.33	1.2995+04	2.2838+04	2.2451+04
16.67	1.4087+04	2.5682+04	2.4050+04
17.00	1.5108+04	2.2152+04	2.1586+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
2.5805+03	3.3696+04	1.7885+03	2.3919+04

3.3347-03 3.7818-03 12743 689 569 120

TABLE 17 (sheet 37 of 57)

THETA= 2.5850+00 EV = 5.3917+04 DEG R = 3.0000+04 DEG K

GAMMA= 1.3500+02

PRESSURE= 1.0130+09 (DYNE/CM2) = 9.9975+02 (ATM)

RHO= 4.3692-02 (G/CM3) = 2.7277+00 (LB/FT3)

ZBAR= 1.6766+00

UMAX	DELTA U
16.00	.33

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.33	3.5943+05	3.8647+05	3.8611+05
.67	4.4937+04	8.6668+04	8.6685+04
1.00	1.3354+04	2.9094+04	2.9072+04
1.33	5.7111+03	2.6124+04	2.6043+04
1.67	3.2131+03	4.2201+04	2.9820+04
2.00	2.2291+03	4.0033+04	3.0387+04
2.33	1.7221+03	2.7598+04	2.7439+04
2.67	1.4700+03	3.0832+04	3.0662+04
3.00	1.4713+03	2.1138+04	2.1068+04
3.33	1.7319+03	3.0904+04	2.8946+04
3.67	2.3335+03	1.7636+04	1.7537+04
4.00	2.9441+03	1.7103+04	1.7045+04
4.33	3.2734+03	1.2981+04	1.2940+04
4.67	3.6210+03	1.4646+04	1.4580+04
5.00	3.7802+03	1.8430+04	1.8391+04
5.33	3.8289+03	4.0485+04	4.0304+04
5.67	3.9099+03	8.2526+04	6.6538+04
6.00	3.8302+03	6.9352+04	6.8999+04
6.33	3.7322+03	8.9988+04	8.9441+04
6.67	3.6297+03	1.0380+05	9.2805+04
7.00	3.4612+03	1.0772+05	1.0095+05
7.33	3.2789+03	1.0252+05	9.1459+04
7.67	3.1308+03	9.6592+04	8.5608+04
8.00	3.1378+03	8.5735+04	7.8099+04
8.33	3.4423+03	7.3229+04	6.8398+04
8.67	4.1212+03	6.2369+04	5.8668+04
9.00	5.0303+03	5.1272+04	4.7785+04
9.33	6.0677+03	3.9016+04	3.7815+04
9.67	6.3924+03	2.6996+04	2.6892+04
10.00	6.6707+03	1.9248+04	1.9193+04
10.33	6.8371+03	1.7243+04	1.7209+04
10.67	6.7628+03	2.5107+04	2.5099+04
11.00	6.6321+03	3.4366+04	3.4154+04
11.33	6.5640+03	5.0432+04	5.0240+04
11.67	6.5508+03	5.1493+04	5.1241+04
12.00	6.6771+03	5.6950+04	5.5891+04
12.33	6.9699+03	6.0164+04	5.8753+04
12.67	7.3857+03	6.0522+04	5.8588+04
13.00	7.7372+03	5.6253+04	5.2964+04
13.33	8.2298+03	4.3485+04	4.2964+04
13.67	8.9127+03	3.1216+04	3.1099+04
14.00	9.8813+03	2.4020+04	2.3941+04
14.33	1.0954+04	2.2106+04	2.2050+04
14.67	1.1656+04	2.4524+04	2.2865+04
15.00	1.2263+04	2.5358+04	2.1415+04
15.33	1.2594+04	2.1683+04	2.1107+04
15.67	1.2822+04	2.0024+04	2.0020+04
16.00	1.2965+04	1.8065+04	1.8065+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
4.8146+03	3.5518+04	2.6410+03	2.5731+04

3.6335-03 4.1008-03 9918 587 479 108

TABLE 17 (sheet 38 of 57)

THETA= 3.4467+00 EV = 7.189C+04 DEG R = 4.0000+04 DEG K

GAMMA= 2.6980+03

PRESSURE= 1.0121+08 (DYNE/CM2) = 9.9886+01 (ATM)

RHO= 2.0620-03 (G/CM3) = 1.2873-01 (LB/FT3)

ZBAR= 2.7368+00

UMAX	DELTA U
19.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	7.3591+03	2.2717+04	2.2677+04
1.00	1.2176+03	1.3542+04	1.3576+04
1.50	5.0597+02	1.2118+04	1.1271+04
2.00	3.1696+02	1.3245+04	1.3159+04
2.50	2.1519+02	1.2666+04	1.2117+04
3.00	2.9176+02	1.7979+04	1.3332+04
3.50	2.0494+02	6.7672+03	6.1710+03
4.00	2.3472+02	9.4515+03	9.3612+03
4.50	2.8366+02	3.8094+04	3.4205+04
5.00	3.4056+02	1.1424+05	8.9564+04
5.50	2.8194+02	9.8030+04	8.0508+04
6.00	3.1660+02	1.0108+05	7.5555+04
6.50	5.4478+02	5.4520+04	3.9131+04
7.00	9.3704+02	3.2753+04	2.4723+04
7.50	1.1755+03	2.7054+04	1.9581+04
8.00	1.2840+03	2.8075+04	2.4789+04
8.50	1.2598+03	5.2137+04	4.4678+04
9.00	1.4490+03	5.8322+04	4.7185+04
9.50	2.1266+03	6.0477+04	4.5612+04
10.00	3.0047+03	3.5311+04	2.6797+04
10.50	4.2430+03	1.9573+04	1.6127+04
11.00	5.1654+03	1.5134+04	1.3486+04
11.50	6.1356+03	1.2130+04	1.2096+04
12.00	6.9004+03	1.3235+04	1.3225+04
12.50	7.7821+03	1.7786+04	1.7239+04
13.00	9.1603+03	1.4750+04	1.4732+04
13.50	1.0219+04	.6765+04	1.6478+04
14.00	1.1583+04	..6923+04	1.6901+04
14.50	1.2318+04	1.7362+04	1.7288+04
15.00	1.3017+04	1.6554+04	1.6534+04
15.50	1.4088+04	1.6357+04	1.6351+04
16.00	1.4331+04	1.7312+04	1.7307+04
16.50	1.5229+04	1.6376+04	1.6366+04
17.00	1.5128+04	1.6485+04	1.6474+04
17.50	1.5255+04	1.6710+04	1.6699+04
18.00	1.5126+04	1.6537+04	1.6526+04
18.50	1.5086+04	1.5887+04	1.5875+04
19.00	1.5262+04	1.5682+04	1.5671+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
5.0018+02	3.1540+04	3.2045+02	1.5445+04

5.8900-04 4.2663-03 15168 1465 1254 211

TABLE 17 (sheet 39 of 57)

THETA= 3.4467+00 EV = 7.1890+04 DEG R = 4.0000+04 DEG K

GAMMA= 1.3490+03

PRESSURE= 2.0230+08 (DYNE/CM2) = 1.9966+02 (ATM)

RHO= 4.4092-03 (G/CM3) = 2.7527-01 (LB/FT3)

ZBAR= 2.5598+00

UMAX	DELTA U
18.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	1.2998+04	3.3422+04	3.3319+04
1.00	1.9915+03	1.6257+04	1.5643+04
1.50	7.9239+02	1.4847+04	1.4756+04
2.00	4.7997+02	1.5408+04	1.5257+04
2.50	3.3661+02	1.5167+04	1.4959+04
3.00	4.6036+02	1.8118+04	1.6755+04
3.50	3.4402+02	7.6029+03	7.5452+03
4.00	3.9487+02	1.3471+04	1.3352+04
4.50	4.7191+02	4.4535+04	4.3448+04
5.00	5.2026+02	1.1597+05	1.0787+05
5.50	4.4654+02	9.9466+04	9.0665+04
6.00	4.8493+02	9.8205+04	8.4387+04
6.50	8.2181+02	5.1523+04	4.4350+04
7.00	1.4457+03	2.9600+04	2.6902+04
7.50	1.7968+03	2.2854+04	2.0738+04
8.00	1.9362+03	2.6401+04	2.5619+04
8.50	1.9092+03	5.0626+04	4.7353+04
9.00	2.0842+03	5.8684+04	5.3317+04
9.50	2.7767+03	5.9381+04	5.2052+04
10.00	3.6817+03	3.3450+04	2.9853+04
10.50	4.9505+03	1.6426+04	1.5971+04
11.00	5.9483+03	1.3908+04	1.3435+04
11.50	6.9475+03	1.2551+04	1.2539+04
12.00	7.7433+03	1.4308+04	1.4299+04
12.50	8.6702+03	1.9636+04	1.9024+04
13.00	1.0259+04	1.5636+04	1.5618+04
13.50	1.1187+04	1.7783+04	1.7362+04
14.00	1.2486+04	1.7546+04	1.7529+04
14.50	1.3156+04	1.8291+04	1.8277+04
15.00	1.3769+04	1.7465+04	1.7457+04
15.50	1.4910+04	1.7346+04	1.7342+04
16.00	1.5105+04	1.8596+04	1.8389+04
16.50	1.6282+04	1.7354+04	1.7352+04
17.00	1.6035+04	1.7333+04	1.7329+04
17.50	1.6232+04	1.7547+04	1.7535+04
18.00	1.6050+04	1.7176+04	1.7164+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
7.7214+02	3.3028+04	5.1100+02	1.8995+04

7.8370-04	3.8683-03	13644	1244	1067	177

TABLE 17 (sheet 40 of 57)

THETA= 3.4467+00 EV = 7.1890+04 DEG R = 4.0000+04 DEG K

GAMMA= 5.3700+02

PRESSURE= 5.0539+08 (DYNE/CM2) = 4.9878+02 (ATM)

RHO= 1.2153-02 (G/CM3) = 7.5872-01 (LB/FT3)

ZBAR= 2.3330+00

UMAX	DELTA U
18.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	2.7521+04	5.3853+04	5.2685+04
1.00	3.5819+03	2.0651+04	2.0390+04
1.50	1.3331+03	1.9209+04	1.9078+04
2.00	7.5892+02	1.8416+04	1.8272+04
2.50	5.5717+02	1.8612+04	1.8526+04
3.00	8.0070+02	1.8056+04	1.7933+04
3.50	6.5690+02	8.9541+03	8.8955+03
4.00	7.6801+02	2.0435+04	2.0348+04
4.50	8.7919+02	5.1930+04	5.1516+04
5.00	8.9988+02	1.1343+05	1.0949+05
5.50	7.9299+02	9.8846+04	9.3522+04
6.00	8.2441+02	9.3606+04	8.5766+04
6.50	1.3139+03	5.0059+04	4.8360+04
7.00	2.2652+03	2.9663+04	2.8208+04
7.50	2.7708+03	2.1321+04	2.1173+04
8.00	2.9876+03	2.6163+04	2.5972+04
8.50	2.9327+03	4.8032+04	4.7616+04
9.00	3.0713+03	5.7696+04	5.5746+04
9.50	3.7467+03	5.6819+04	5.3961+04
10.00	4.6453+03	3.2634+04	3.1675+04
10.50	5.8977+03	1.5285+04	1.5243+04
11.00	7.0080+03	1.3794+04	1.3744+04
11.50	7.9814+03	1.3927+04	1.3910+04
12.00	8.8030+03	1.5876+04	1.5865+04
12.50	9.7714+03	2.1709+04	2.0720+04
13.00	1.1705+04	1.6887+04	1.6873+04
13.50	1.2419+04	1.9155+04	1.8245+04
14.00	1.3689+04	1.8474+04	1.8202+04
14.50	1.4297+04	1.9617+04	1.9615+04
15.00	1.4776+04	1.8781+04	1.8781+04
15.50	1.5955+04	1.8781+04	1.8778+04
16.00	1.6108+04	2.0321+04	1.9952+04
16.50	1.7661+04	1.8709+04	1.8706+04
17.00	1.7217+04	1.8481+04	1.8480+04
17.50	1.7540+04	1.8750+04	1.8740+04
18.00	1.7307+04	1.8304+04	1.8293+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.3287+03	3.5001+04	8.9625+02	2.2606+04

2.0264-02	3.6120-03	12492	982	829	153

TABLE 17 (sheet 41 of 57)

THETA= 3.44b7+00 EV = 7.1890+04 DEG R = 4.0000+04 DEG K

GAMMA= 2.6500+02

PRESSURE= 1.0109+09 (DYNE/CM2) = 9.9765+02 (ATM)

RHO= 2.6318-02 (G/CM3) = 1.6430+00 (LB/FT3)

ZBAR= 2.1831+00

UMAX	DELTA U
17.00	.50

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.50	4.9505+04	8.2186+04	8.2065+04
1.00	6.2035+03	2.6358+04	2.4946+04
1.50	2.1786+03	2.4217+04	2.3184+04
2.00	1.1509+03	2.1465+04	2.1353+04
2.50	8.4077+02	2.1726+04	2.1662+04
3.00	1.2489+03	1.8698+04	1.8644+04
3.50	1.0946+03	1.0358+04	1.0306+04
4.00	1.2942+03	2.6340+04	2.6310+04
4.50	1.4218+03	5.6568+04	5.6422+04
5.00	1.4005+03	1.1129+05	1.1080+05
5.50	1.2455+03	1.0022+05	9.3383+04
6.00	1.2503+03	9.3542+04	8.3888+04
6.50	1.8362+03	5.1981+04	5.0650+04
7.00	3.0170+03	3.1463+04	2.9695+04
7.50	3.6263+03	2.1865+04	2.1737+04
8.00	3.8896+03	2.7208+04	2.7087+04
8.50	3.8061+03	4.7322+04	4.7084+04
9.00	3.9067+03	5.7942+04	5.7026+04
9.50	4.5465+03	5.6271+04	5.4755+04
10.00	5.4168+03	3.3802+04	3.3452+04
10.50	6.6310+03	1.6281+04	1.6240+04
11.00	7.8767+03	1.4716+04	1.4680+04
11.50	8.7738+03	1.5362+04	1.5233+04
12.00	9.6208+03	1.6907+04	1.6896+04
12.50	1.0600+04	2.2490+04	2.1100+04
13.00	1.2801+04	1.7679+04	1.7664+04
13.50	1.3335+04	1.9975+04	1.8600+04
14.00	1.4601+04	1.9119+04	1.9114+04
14.50	1.5216+04	2.0550+04	2.0550+04
15.00	1.5542+04	1.9678+04	1.9678+04
15.50	1.6674+04	1.9767+04	1.9765+04
16.00	1.6808+04	2.1349+04	2.0795+04
16.50	1.8600+04	1.9564+04	1.9561+04
17.00	1.8021+04	1.9007+04	1.9007+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
2.0770+03	3.7426+04	1.3961+03	2.5543+04

2.3898-02	3.7050-03	9880	834	700	134

TABLE 17 (sheet 42 of 57)

THETA= 4.3084+00 EV = 8.9862+04 DEG R = 5.0000+04 DEG K

GAMMA= 4.5200+03

PRESSURE= 1.0164+08 (DYNE/CM2) = 1.0031+02 (ATM)

RHO= 1.4121-03 (G/CM3) = 8.8158-02 (LB/FT3)

ZBAR= 3.3337+00

UMAX	DELTA U
20.00	.40

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.40	8.0564+03	2.1162+04	2.1123+04
.80	1.3144+03	1.3628+04	1.4188+04
1.20	5.1203+02	9.6053+03	7.5875+03
1.60	3.0296+02	9.8319+03	9.1941+03
2.00	1.6173+02	9.4165+03	8.3864+03
2.40	1.9803+02	1.3587+04	9.8387+03
2.80	1.2235+02	6.0077+03	5.1825+03
3.20	1.3247+02	4.6176+03	4.5393+03
3.60	1.1603+02	1.9854+04	1.6192+04
4.00	1.9393+02	6.4371+04	4.6109+04
4.40	1.5075+02	5.9695+04	4.7190+04
4.80	1.5330+02	7.5409+04	5.4278+04
5.20	2.0447+02	6.7875+04	3.9774+04
5.60	2.4710+02	8.0034+04	3.6267+04
6.00	3.1542+02	7.9828+04	3.5197+04
6.40	3.0346+02	5.6448+04	3.2800+04
6.80	3.0928+02	4.9335+04	3.7280+04
7.20	4.2086+02	4.1152+04	3.1993+04
7.60	7.7430+02	4.5087+04	3.0714+04
8.00	1.1772+03	5.0137+04	2.8061+04
8.40	1.7370+03	5.0243+04	2.4245+04
8.80	2.1270+03	3.0516+04	1.8117+04
9.20	2.5787+03	1.9752+04	1.4774+04
9.60	3.0075+03	1.4600+04	1.3356+04
10.00	3.5986+03	1.3656+04	1.2918+04
10.40	4.3653+03	1.3029+04	1.3003+04
10.80	5.6088+03	1.4682+04	1.4556+04
11.20	7.3020+03	1.5691+04	1.5575+04
11.60	8.2436+03	1.4803+04	1.4576+04
12.00	9.3798+03	1.5051+04	1.4983+04
12.40	1.0373+04	1.4660+04	1.4639+04
12.80	1.1074+04	1.4521+04	1.4518+04
13.20	1.1507+04	1.4050+04	1.4047+04
13.60	1.1863+04	1.4227+04	1.4217+04
14.00	1.1978+04	1.4112+04	1.4103+04
14.40	1.2101+04	1.4400+04	1.4390+04
14.80	1.2013+04	1.3631+04	1.3622+04
15.20	1.2203+04	1.3624+04	1.3615+04
15.60	1.2181+04	1.3333+04	1.3331+04
16.00	1.2191+04	1.6333+04	1.5482+04
16.40	1.2121+04	1.3944+04	1.3940+04
16.80	1.2039+04	1.4963+04	1.4785+04
17.20	1.1944+04	1.9855+04	1.6188+04
17.60	1.1835+04	1.3419+04	1.3314+04
18.00	1.1555+04	1.3351+04	1.3341+04
18.40	1.1390+04	1.2138+04	1.2129+04
18.80	1.1077+04	1.1729+04	1.1721+04
19.20	1.0890+04	1.1418+04	1.1410+04
19.60	1.0660+04	1.1165+04	1.1158+04
20.00	1.0536+04	1.1648+04	1.1640+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
3.7038+02	3.2331+04	1.9460+02	1.3223+04

2.8194-03 4.5499-03 21766 1905 1641 264

TABLE 17 (sheet 43 of 57)

THETA= 4.3084+00 EV = 8.9862+04 DEG R = 5.0000+04 DEG K

GAMMA= 2.2720+03

PRESSURE= 2.0224+08 (DYNE/CM2) = 1.9960+02 (ATM)

RHO= 3.0028-03 (G/CM3) = 1.8747-01 (LB/FT3)

ZBAR= 3.1189+00

UMAX	DELTA U
19.00	.40

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.40	1.4126+04	3.1434+04	3.1382+04
.80	2.1918+03	1.7100+04	1.7290+04
1.20	8.2642+02	1.1339+04	1.0058+04
1.60	4.7214+02	1.1517+04	1.1286+04
2.00	2.6071+02	1.0721+04	1.0564+04
2.40	2.9907+02	1.5473+04	1.2805+04
2.80	1.8734+02	6.6128+03	6.2736+03
3.20	1.9637+02	6.2476+03	6.1977+03
3.60	1.8430+02	2.6316+04	2.5321+04
4.00	2.7432+02	7.9768+04	6.3352+04
4.40	1.9464+02	6.9762+04	6.1193+04
4.80	2.2260+02	7.8502+04	6.4072+04
5.20	3.0828+02	6.0073+04	4.4647+04
5.60	4.1701+02	6.3576+04	4.0033+04
6.00	5.3206+02	6.3024+04	3.7807+04
6.40	5.3960+02	4.8150+04	3.5617+04
6.80	5.3661+02	5.0985+04	4.4538+04
7.20	6.7266+02	4.5224+04	3.9829+04
7.60	1.1276+03	4.6498+04	3.7877+04
8.00	1.6449+03	4.1467+04	3.0291+04
8.40	2.3642+03	3.6645+04	2.3817+04
8.80	2.8629+03	2.2644+04	1.6824+04
9.20	3.4256+03	1.4629+04	1.3272+04
9.60	3.9255+03	1.2552+04	1.2503+04
10.00	4.6032+03	1.4625+04	1.4089+04
10.40	5.5472+03	1.3522+04	1.3497+04
10.80	6.7570+03	1.5443+04	1.5228+04
11.20	8.3581+03	1.6009+04	1.5943+04
11.60	9.2609+03	1.5659+04	1.5493+04
12.00	1.0298+04	1.4945+04	1.4906+04
12.40	1.1363+04	1.4603+04	1.4597+04
12.80	1.1940+04	1.4974+04	1.4970+04
13.20	1.2480+04	1.4431+04	1.4428+04
13.60	1.2710+04	1.4683+04	1.4673+04
14.00	1.2797+04	1.4708+04	1.4698+04
14.40	1.2730+04	1.5058+04	1.5048+04
14.80	1.2725+04	1.4262+04	1.4253+04
15.20	1.2885+04	1.3951+04	1.3941+04
15.60	1.2845+04	1.4030+04	1.4026+04
16.00	1.2878+04	1.8913+04	1.8382+04
16.40	1.2809+04	1.5375+04	1.5358+04
16.80	1.2736+04	1.5889+04	1.5849+04
17.20	1.2654+04	2.0924+04	1.7939+04
17.60	1.2547+04	1.4171+04	1.4145+04
18.00	1.2203+04	1.4325+04	1.4322+04
18.40	1.1979+04	1.2862+04	1.2854+04
18.80	1.1600+04	1.2220+04	1.2212+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
5.4529+02	3.3458+04	2.9841+02	1.6548+04

3.9099-03 5.2777-03 14529 1185 956 229

TABLE 17 (sheet 44 of 57)

THETA= 4.3084+00 EV = 8.9862+04 DEG R = 5.0000+04 DEG K

GAMMA= 9.0400+02

PRESSURE= 5.0517+08 (DYNE/CM2) = 4.9856+02 (ATM)

RHO= 8.2138-03 (G/CM3) = 5.1279-01 (LB/FT3)

ZBAR= 2.8657+00

UMAX	DELTA U
18.00	.40

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.40	3.0214+04	5.2195+04	5.2168+04
.80	3.6144+03	2.2564+04	1.9962+04
1.20	1.3808+03	1.4929+04	1.4856+04
1.60	7.7498+02	1.4478+04	1.4353+04
2.00	4.6415+02	1.3388+04	1.3317+04
2.40	5.2480+02	1.7686+04	1.7248+04
2.80	3.5454+02	7.8065+03	7.7522+03
3.20	3.7647+02	9.9493+03	9.9009+03
3.60	3.8340+02	3.5754+04	3.5314+04
4.00	4.7396+02	9.6500+04	9.0621+04
4.40	3.6842+02	8.1630+04	7.7468+04
4.80	3.9850+02	8.2537+04	7.4334+04
5.20	5.6495+02	5.3454+04	4.8150+04
5.60	8.4734+02	4.8243+04	3.9777+04
6.00	1.0674+03	4.6342+04	3.7229+04
6.40	1.1170+03	4.0058+04	3.7513+04
6.80	1.0997+03	5.2131+04	4.9548+04
7.20	1.2450+03	5.0277+04	4.7559+04
7.60	1.7969+03	4.8886+04	4.4555+04
8.00	2.4329+03	3.4613+04	3.1536+04
8.40	3.3162+03	2.5226+04	2.2210+04
8.80	3.9575+03	1.7624+04	1.6081+04
9.20	4.0349+03	1.3128+04	1.3094+04
9.60	5.2166+03	1.3113+04	1.3093+04
10.00	5.9939+03	1.6847+04	1.6133+04
10.40	7.2032+03	1.4489+04	1.4468+04
10.80	8.3182+03	1.6561+04	1.6123+04
11.20	9.8000+03	1.6959+04	1.6928+04
11.60	1.0636+04	1.6973+04	1.6906+04
12.00	1.1524+04	1.6098+04	1.6085+04
12.40	1.2660+04	1.5775+04	1.5771+04
12.80	1.3098+04	1.6488+04	1.6485+04
13.20	1.3875+04	1.5578+04	1.5575+04
13.60	1.3929+04	1.5739+04	1.5729+04
14.00	1.4043+04	1.5866+04	1.5855+04
14.40	1.3938+04	1.6092+04	1.6081+04
14.80	1.3928+04	1.5329+04	1.5320+04
15.20	1.4133+04	1.4982+04	1.4981+04
15.60	1.4043+04	1.5474+04	1.5469+04
16.00	1.4076+04	2.3557+04	2.2537+04
16.40	1.3990+04	1.7740+04	1.7716+04
16.80	1.3905+04	1.7181+04	1.7157+04
17.20	1.3824+04	2.1291+04	1.9648+04
17.60	1.3689+04	1.5253+04	1.5245+04
18.00	1.3232+04	1.5581+04	1.5579+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
9.2648+02	3.5834+04	5.5704+02	2.1062+04

4.4429-03	4.0720-03	16720	1241	1043	198

TABLE 17 (sheet 45 of 57)

THETA= 4.3084+00 EV = 8.9862+04 DEG R = 5.0000+04 DEG K

GAMMA= 4.4600+02

PRESSURE= 1.0139+09 (DYNE/CM2) = 1.0006+03 (ATM)

RHO= 1.7787-02 (G/CM3) = 1.1105+00 (LB/FT3)

ZBAR= 2.6822+00

UMAX	DELTA U
17.00	.40

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.40	5.4137+04	8.1764+04	8.1724+04
.80	6.8545+03	2.8463+04	2.5269+04
1.20	2.3031+03	1.8874+04	1.8743+04
1.60	1.2302+03	1.7179+04	1.7072+04
2.00	7.5641+02	1.5980+04	1.5888+04
2.40	8.4933+02	1.8915+04	1.8947+04
2.80	5.9305+02	8.9301+03	8.8841+03
3.20	6.2838+02	1.3832+04	1.3775+04
3.60	6.5195+02	4.3047+04	4.2727+04
4.00	7.4151+02	1.0442+05	1.0333+05
4.40	5.9048+02	8.7662+04	8.4360+04
4.80	6.1283+02	8.3785+04	7.7921+04
5.20	8.5962+02	5.0492+04	4.8284+04
5.60	1.3300+03	4.1615+04	3.6188+04
6.00	1.6548+03	3.8286+04	3.3583+04
6.40	1.7508+03	3.6142+04	3.5761+04
6.80	1.7146+03	5.1627+04	4.7868+04
7.20	1.8464+03	5.2526+04	5.1627+04
7.60	2.4349+03	4.9779+04	4.7766+04
8.00	3.1252+03	3.1816+04	3.1062+04
8.40	4.0840+03	2.0145+04	1.9855+04
8.80	4.8299+03	1.5507+04	1.5119+04
9.20	5.5572+03	1.2911+04	1.2895+04
9.60	6.1875+03	1.3890+04	1.3881+04
10.00	7.0205+03	1.8530+04	1.7540+04
10.40	8.4411+03	1.5240+04	1.5221+04
10.80	9.4512+03	1.7413+04	1.6584+04
11.20	1.0858+04	1.7525+04	1.7499+04
11.60	1.1643+04	1.7858+04	1.7841+04
12.00	1.2418+04	1.6939+04	1.6931+04
12.40	1.3603+04	1.6687+04	1.6683+04
12.80	1.3955+04	1.7677+04	1.7351+04
13.20	1.4965+04	1.6502+04	1.6500+04
13.60	1.4871+04	1.6561+04	1.6561+04
14.00	1.5035+04	1.6738+04	1.6729+04
14.40	1.4893+04	1.6796+04	1.6787+04
14.80	1.4868+04	1.5940+04	1.5938+04
15.20	1.5092+04	1.5980+04	1.5980+04
15.60	1.4949+04	1.6611+04	1.6604+04
16.00	1.4959+04	2.7709+04	2.5484+04
16.40	1.4845+04	1.9540+04	1.9511+04
16.80	1.4734+04	1.7002+04	1.6987+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.4174+03	3.7772+04	8.8768+02	2.3866+04

5.2757-03 3.6117-03 14708 968 801 167

EXIT CALLED FROM 024251

TABLE 17 (sheet 46 of 57)

THETA= 6.0318+00 EV = 1.2581+05 DEG R = 7.0000+04 DEG K

GAMMA= 1.0080+04

PRESSURE= 1.0131+08 (DYNE/CM2) = 9.9981+01 (ATM)

RHO= 7.9465-04 (G/CM3) = 4.9610-02 (LB/FT3)

ZBAR= 4.4004+00

UMAX	DELTA U
20.00	.57

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.57	1.2649+03	5.9417+03	5.9143+03
1.14	2.2878+02	4.9873+03	5.0733+03
1.71	1.0693+02	6.6093+03	4.6871+03
2.29	6.6972+01	4.1727+03	4.0648+03
2.86	4.9596+01	9.4147+03	9.3279+03
3.43	3.8042+01	3.1256+04	2.2575+04
4.00	6.2409+01	5.5007+04	3.2157+04
4.57	4.2632+01	5.3507+04	2.6386+04
5.14	5.7758+01	2.7817+04	1.7607+04
5.71	9.1204+01	4.6027+04	2.1521+04
6.29	1.5187+02	3.9841+04	2.3156+04
6.86	3.9114+02	3.1157+04	1.6477+04
7.43	9.9813+02	2.2989+04	1.3235+04
8.00	2.3454+03	2.0511+04	1.4802+04
8.57	2.9210+03	1.8132+04	1.4976+04
9.14	4.8991+03	1.5481+04	1.4211+04
9.71	6.0093+03	1.1866+04	1.1852+04
10.29	7.8926+03	1.1896+04	1.1799+04
10.86	7.7998+03	1.1143+04	1.1120+04
11.43	8.4530+03	1.1287+04	1.1284+04
12.00	8.3835+03	1.2851+04	1.2074+04
12.57	8.3306+03	1.0245+04	1.0140+04
13.14	8.2971+03	9.7824+03	9.6239+03
13.71	8.0571+03	1.1648+04	8.9278+03
14.29	7.7364+03	1.2027+04	1.0165+04
14.86	7.1912+03	1.0426+04	8.9095+03
15.43	6.6439+03	1.0702+04	8.1050+03
16.00	5.9897+03	9.7777+03	7.4244+03
16.57	5.4283+03	1.0374+04	6.4265+03
17.14	4.6823+03	1.3163+04	7.1202+03
17.71	4.1213+03	1.7383+04	8.8284+03
18.29	3.6266+03	3.0645+04	1.4611+04
18.86	3.2076+03	8.7071+04	2.3128+04
19.43	2.8348+03	6.3306+04	2.2541+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
3.2114+02	2.4557+04	7.0814+01	1.0761+04

3.8900-03 6.6795-03 14941 1842 1442 400

TABLE 17 (sheet 47 of 57)

THETA= 6.0318+00 EV = 1.2581+05 DEG R = 7.0000+04 DEG K

GAMMA= 5.0500+03

PRESSURE= 2.0215+08 (DYNE/CM2) = 1.9950+02 (ATM)

RHO= 1.6862-03 (G/CM3) = 1.0527-01 (LB/FT3)

ZBAR= 4.1394+00

UMAX	DELTA U
20.00	.57

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.57	1.9373+03	8.5321+03	8.4876+03
1.14	3.3470+02	6.6488+03	6.6991+03
1.71	1.6363+02	8.0008+03	6.9801+03
2.29	9.9717+01	5.3474+03	5.2957+03
2.86	8.9003+01	1.4044+04	1.3971+04
3.43	5.9708+01	4.1422+04	3.3200+04
4.00	9.8800+01	6.8029+04	4.7912+04
4.57	7.4642+01	6.3731+04	3.9497+04
5.14	8.6328+01	3.3195+04	2.5368+04
5.71	1.6969+02	5.3617+04	2.9060+04
6.29	2.7071+02	4.1221+04	2.7994+04
6.86	5.9218+02	2.6871+04	1.7910+04
7.43	1.4533+03	1.9685+04	1.4488+04
8.00	3.2190+03	1.8625+04	1.5260+04
8.57	3.9443+03	1.7244+04	1.5947+04
9.14	6.2785+03	1.5367+04	1.4381+04
9.71	7.2570+03	1.2245+04	1.2242+04
10.29	8.9301+03	1.2250+04	1.2223+04
10.86	8.8635+03	1.1549+04	1.1544+04
11.43	9.3011+03	1.1874+04	1.1873+04
12.00	9.1602+03	1.5095+04	1.3190+04
12.57	9.0073+03	1.1271+04	1.1192+04
13.14	8.9709+03	1.0103+04	1.0076+04
13.71	8.6450+03	1.1189+04	9.4349+03
14.29	8.3360+03	1.2494+04	1.0321+04
14.86	7.7080+03	1.1673+04	9.2960+03
15.43	7.0338+03	1.2182+04	8.6595+03
16.00	6.2805+03	1.0817+04	7.9452+03
16.57	5.7027+03	1.0624+04	6.9983+03
17.14	4.9005+03	1.2529+04	8.4543+03
17.71	4.3454+03	2.0385+04	1.1665+04
18.29	3.8336+03	3.9067+04	2.2351+04
18.86	3.4058+03	1.1024+05	3.9999+04
19.43	3.0358+03	8.1322+04	4.0142+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
4.3376+02	2.9460+04	1.1535+02	1.4338+04

2.9265-03	5.0389-03	17649	2052	1700	352

TABLE 17 (sheet 48 of 57)

THETA= 6.0318+00 EV = 1.2581+05 DEG R = 7.0000+04 DEG K

GAMMA= 2.0050+03

PRESSURE= 5.0635+08 (DYNE/CM2) = 4.9972+02 (ATM)

RHO= 4.5856-03 (G/CM3) = 2.8628-01 (LB/FT3)

ZBAR= 3.8337+00

UMAX	DELTA U
19.00	.57

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.57	4.1784+03	1.4171+04	1.4116+04
1.14	6.8170+02	9.2590+03	9.2170+03
1.71	3.2053+02	9.9515+03	9.0956+03
2.29	1.7949+02	6.8201+03	6.7636+03
2.86	1.8685+02	2.1853+04	2.1874+04
3.43	1.1405+02	5.2645+04	4.7088+04
4.00	1.8118+02	7.7206+04	6.5562+04
4.57	1.5590+02	7.1778+04	5.6150+04
5.14	1.9625+02	3.8827+04	3.5308+04
5.71	3.6085+02	5.5528+04	3.6242+04
6.29	5.4328+02	3.7832+04	3.1090+04
6.86	9.5373+02	1.8517+04	1.5676+04
7.43	2.1762+03	1.5215+04	1.3251+04
8.00	4.3018+03	1.5647+04	1.4865+04
8.57	5.2155+03	1.4825+04	1.4476+04
9.14	7.8654+03	1.4017+04	1.3818+04
9.71	8.6407+03	1.2220+04	1.2218+04
10.29	1.0015+04	1.2185+04	1.2183+04
10.86	1.0006+04	1.1473+04	1.1465+04
11.43	1.0182+04	1.2400+04	1.2399+04
12.00	9.9618+03	1.8040+04	2.1478+04
12.57	9.6730+03	1.2456+04	1.2667+04
13.14	9.6023+03	1.0301+04	1.0301+04
13.71	9.1508+03	9.6691+03	9.5972+03
14.29	8.8640+03	1.2175+04	1.1037+04
14.86	8.1226+03	1.2640+04	1.0297+04
15.43	7.3126+03	1.3331+04	9.7947+03
16.00	6.4702+03	1.1613+04	8.4989+03
16.57	5.9065+03	1.0691+04	7.8164+03
17.14	5.0545+03	1.2007+04	9.6273+03
17.71	4.5315+03	2.3803+04	1.6618+04
18.29	4.0164+03	4.3749+04	3.1243+04
18.86	3.5932+03	9.2848+04	3.8361+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
8.4893+02	3.3756+04	1.2300+02	1.7867+04

3.2691-03	4.8984-03	12727	1318	1034	284

TABLE 17 (sheet 49 of 57)

THETA= 6.0318+00 EV = 1.2581+05 DEG R = 7.0000+04 DEG K

GAMMA= 9.9300+02

PRESSURE= 1.0139+09 (DYNE/CM2) = 1.0007+03 (ATM)

RHO= 9.8191-03 (G/CM3) = 6.1301-01 (LB/FT3)

ZBAR= 3.6150+00

UMAX	DELTA U
18.00	.57

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.57	7.5328+03	2.0596+04	2.0837+04
1.14	1.1740+03	1.1593+04	1.1563+04
1.71	5.2594+02	1.1493+04	1.1344+04
2.29	2.7851+02	8.0368+03	7.9950+03
2.86	3.0445+02	2.9208+04	2.9356+04
3.43	1.8122+02	5.8678+04	5.3799+04
4.00	2.8667+02	7.7590+04	7.2368+04
4.57	2.6675+02	7.3010+04	6.4728+04
5.14	2.5585+02	4.1675+04	4.0500+04
5.71	6.0002+02	5.1382+04	3.8287+04
6.29	8.6648+02	3.4412+04	3.2131+04
6.86	1.3288+03	1.6817+04	1.5791+04
7.43	2.8461+03	1.4103+04	1.3715+04
8.00	5.0648+03	1.4840+04	1.4707+04
8.57	6.1147+03	1.4498+04	1.3979+04
9.14	8.8919+03	1.4434+04	1.4415+04
9.71	9.5219+03	1.2875+04	1.2874+04
10.29	1.0703+04	1.3210+04	1.3110+04
10.86	1.0761+04	1.2163+04	1.2169+04
11.43	1.0820+04	1.3671+04	1.3665+04
12.00	1.0849+04	2.0959+04	3.9621+04
12.57	1.0387+04	1.3845+04	1.4188+04
13.14	1.0301+04	1.0926+04	1.0925+04
13.71	9.7974+03	1.0363+04	1.0331+04
14.29	9.4964+03	1.2814+04	1.2033+04
14.86	8.6329+03	1.3[illegible]2+04	1.1422+04
15.43	7.7597+03	1.39[illegible]8+04	1.1071+04
16.00	6.8488+03	1.2114+04	9.5282+03
16.57	6.3108+03	1.0949+04	8.8403+03
17.14	5.4181+03	1.[illegible]767+04	1.0583+04
17.71	4.9123+03	1.6613+04	1.1815+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
8.9161+02	3.5665+04	3.6003+02	2.0466+[illegible]

3.9704-03	4.3062-03	11588	1216	980	236

TABLE 17 (sheet 50 of 57)

THETA= 7.7551+00 EV = 1.6175+05 DEG R = 9.0000+04 DEG K

GAMMA= 1.8236+04

PRESSURE= 1.0137+08 (DYNE/CM2) = 1.0005+02 (ATM)

RHO= 4.9888-04 (G/CM3) = 3.1145-02 (LB/FT3)

ZBAR= 5.6484+00

UMAX	DELTA U
20.00	.44

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.44	1.3346+03	4.9983+03	4.9747+03
.89	2.2662+02	2.0585+03	1.9500+03
1.33	8.9891+01	3.9111+03	1.5434+03
1.78	5.4045+01	2.4206+03	1.1331+03
2.22	2.6575+01	1.0092+03	9.6900+02
2.67	3.2220+01	3.0445+03	2.1692+03
3.11	2.4018+01	8.0870+03	4.8028+03
3.56	2.0360+01	1.3553+04	6.2786+03
4.00	3.5804+01	1.4867+04	6.1062+03
4.44	2.2926+01	1.9163+04	8.5403+03
4.89	3.0937+01	4.5831+04	1.4424+04
5.33	4.6255+01	4.2495+04	1.3969+04
5.78	8.0668+01	3.2571+04	1.2357+04
6.22	1.5985+02	2.1219+04	1.3231+04
6.67	3.3968+02	1.5903+04	1.3321+04
7.11	7.9853+02	1.4321+04	1.2133+04
7.56	1.3663+03	1.4322+04	1.2655+04
8.[illegible]	1.9430+03	1.3489+04	1.2683+04
8.	2.1796+03	1.1077+04	1.0939+04
8.89	3.0253+03	9.8411+03	9.8265+03
9.33	4.2484+03	9.7977+03	9.7953+03
9.78	5.3846+03	7.9988+03	7.9918+03
10.22	5.9336+03	9.0555+03	8.2738+03
10.67	6.1967+03	1.3849+04	8.6846+03
11.11	5.6623+03	1.0346+04	8.2316+03
11.56	5.1357+03	6.8027+03	6.7995+03
12.00	4.8046+03	6.7276+03	6.2277+03
12.44	4.3881+03	8.1348+03	6.1006+03
12.89	4.0578+03	7.9876+03	5.5318+03
13.33	3.7208+03	1.0149+04	5.4090+03
13.78	3.4817+03	1.0737+04	5.8296+03
14.22	3.2391+03	1.0370+04	6.5734+03
14.67	2.8911+03	2.1614+04	9.0813+03
15.11	2.4831+03	1.6277+04	7.6504+03
15.56	2.1685+03	1.7679+04	5.8548+03
16.00	1.8493+03	5.9913+04	6.5264+03
16.44	1.9366+03	5.6393+04	8.2091+03
16.89	1.5797+03	1.0289+05	9.8347+03
17.33	1.5458+03	1.3791+05	1.2408+04
17.78	1.3977+03	1.0583+05	1.1560+04
18.22	1.2719+03	1.0496+05	1.0982+04
18.67	1.2188+03	7.5722+04	5.7277+03
19.11	1.0912+03	1.9678+04	2.7201+03
19.56	1.0216+03	9.4114+03	1.9588+03
20.00	9.2674+02	8.7227+03	1.8920+03

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
2.4632+02	1.3565+04	4.0259+01	3.6635+03

5.9380-05 7.1310-03 29358 3538 2917 621

TABLE 17 (sheet 51 of 57)

THETA= 7.7551+00 EV = 1.6175+05 DEG R = 9.0000+04 DEG K

GAMMA= 9.1100+03

PRESSURE= 2.0282+08 (DYNE/CM2) = 2.0017+02 (ATM)

RHO= 1.0624-03 (G/CM3) = 6.6328-02 (LB/FT3)

ZBAR= 5.3092+00

UMAX	DELTA U
20.00	.44

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.44	2.2446+03	6.8596+03	6.8436+03
.89	3.6760+02	3.0896+03	3.0716+03
1.33	1.4764+02	5.1700+03	2.5505+03
1.78	8.6847+01	2.5592+03	1.6866+03
2.22	4.4576+01	2.0801+03	2.0610+03
2.67	4.8842+01	5.9822+03	5.0615+03
3.11	4.2018+01	1.2814+04	9.6216+03
3.56	3.1995+01	1.7319+04	1.1045+04
4.00	5.5339+01	1.5609+04	9.7161+03
4.44	3.6758+01	2.1626+04	1.3511+04
4.89	5.1275+01	4.3787+04	2.1109+04
5.33	9.5993+01	4.4164+04	1.9467+04
5.78	1.6727+02	3.3125+04	1.5374+04
6.22	3.7543+02	2.2387+04	1.5407+04
6.67	6.9480+02	1.8518+04	1.6444+04
7.11	1.4552+03	1.6112+04	1.4410+04
7.56	2.3290+03	1.4341+04	1.3701+04
8.00	3.2082+03	1.3614+04	1.3199+04
8.44	3.5134+03	1.1167+04	1.1148+04
8.89	4.3773+03	1.0350+04	1.0343+04
9.33	5.4102+03	9.8517+03	9.8497+03
9.78	6.3653+03	8.3719+03	8.3539+03
10.22	6.8242+03	9.3397+03	8.9305+03
10.67	6.9993+03	1.5370+04	8.6897+03
11.11	6.4658+03	1.1969+04	8.8110+03
11.56	5.9329+03	7.6256+03	7.4105+03
12.00	5.5793+03	7.5286+03	7.1400+03
12.44	5.1005+03	7.8772+03	6.7434+03
12.89	4.6752+03	8.5946+03	6.3321+03
13.33	4.1949+03	1.1956+04	6.7852+03
13.78	3.8260+03	1.1285+04	7.0072+03
14.22	3.4626+03	1.2543+04	9.1947+03
14.67	3.0626+03	2.5600+04	1.2621+04
15.11	2.6169+03	2.2318+04	1.1976+04
15.56	2.2991+03	2.8099+04	9.4368+03
16.00	1.9665+03	8.5367+04	1.1962+04
16.44	2.0411+03	7.6124+04	1.4914+04
16.89	1.6817+03	9.5061+04	1.5598+04
17.33	1.6331+03	1.1157+05	1.7814+04
17.78	1.4762+03	8.3807+04	1.5406+04
18.22	1.3418+03	7.7041+04	1.3383+04
18.67	1.2600+03	4.9223+04	6.6403+03
19.11	1.1375+03	1.2557+04	3.1754+03
19.56	1.0577+03	5.5817+03	2.1343+03
20.00	9.5402+02	6.4459+03	2.1666+03

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
3.7255+02	1.5152+04	6.7404+01	6.2201+03

1.6494-03 6.5288-03 26555 2766 2244 522

TABLE 17 (sheet 52 of 57)

THETA= 7.7551+00 EV = 1.6175+05 DEG R = 9.0000+04 DEG K

GAMMA= 3.6300+03

PRESSURE= 5.0739+08 (DYNE/CM2) = 5.0075+02 (ATM)

RHO= 2.9022-03 (G/CM3) = 1.8118-01 (LB/FT3)

ZBAR= 4.8778+00

UMAX	DELTA U
19.00	.44

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.44	4.7749+03	1.1773+04	1.1754+04
.89	7.5839+02	5.3893+03	5.4499+03
1.33	2.8913+02	7.0976+03	5.5144+03
1.78	1.6166+02	3.5399+03	3.3300+03
2.22	8.9720+01	5.0335+03	4.9941+03
2.67	8.1057+01	1.3679+04	1.2519+04
3.11	8.4078+01	2.4754+04	2.1548+04
3.56	5.8614+01	2.6406+04	2.0624+04
4.00	8.7670+01	1.8887+04	1.6315+04
4.44	7.4721+01	2.8518+04	2.2176+04
4.89	1.0010+02	4.3339+04	3.0314+04
5.33	2.2369+02	4.2754+04	2.6713+04
5.78	4.7267+02	3.2030+04	1.9811+04
6.22	9.4359+02	2.4983+04	2.0494+04
6.67	1.5231+03	2.1418+04	1.9800+04
7.11	2.7535+03	1.7663+04	1.6606+04
7.56	3.9763+03	1.4425+04	1.4309+04
8.00	5.1873+03	1.4256+04	1.4109+04
8.44	5.5459+03	1.2447+04	1.2430+04
8.89	6.3074+03	1.1606+04	1.1604+04
9.33	6.9458+03	1.1881+04	1.1803+04
9.78	7.5231+03	9.6992+03	9.6987+03
10.22	7.6141+03	9.9446+03	9.7663+03
10.67	7.8212+03	1.6255+04	9.7197+03
11.11	7.3336+03	1.3803+04	1.0063+04
11.56	6.8046+03	9.4538+03	8.8904+03
12.00	6.3876+03	9.4459+03	8.4335+03
12.44	5.8205+03	9.0349+03	7.8969+03
12.89	5.2970+03	9.9312+03	7.3475+03
13.33	4.6694+03	1.3716+04	8.8996+03
13.78	4.1863+03	1.4590+04	1.0694+04
14.22	3.7447+03	1.9581+04	1.6240+04
14.67	3.3006+03	4.0882+04	2.4418+04
15.11	2.8535+03	4.1952+04	2.8952+04
15.56	2.5678+03	5.2001+04	2.4375+04
16.00	2.2150+03	1.0761+05	2.9501+04
16.44	2.2348+03	8.9236+04	3.1188+04
16.89	1.8966+03	7.7130+04	2.6989+04
17.33	1.8120+03	7.2566+04	2.6402+04
17.78	1.6477+03	5.2001+04	2.1153+04
18.22	1.5004+03	4.1412+04	1.5494+04
18.67	1.3791+03	2.4436+04	7.7160+03

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
6.1139+02	1.9058+04	1.2689+02	1.1377+04

2.7556-03 5.2586-03 24380 2349 1963 386

TABLE 17 (sheet 53 of 57)

THETA= 7.7551+00 EV = 1.6175+05 DEG R = 9.0000+04 DEG K

GAMMA= 1.8090+03

PRESSURE= 1.0137+09 (DYNE/CM2) = 1.0004+03 (ATM)

RHO= 6.2372-03 (G/CM3) = 3.8939-01 (LB/FT3)

ZBAR= 4.5543+00

UMAX	DELTA U
18.00	.44

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.44	8.3894+03	1.7905+04	1.7882+04
.89	1.2441+03	7.8243+03	7.7876+03
1.33	4.7538+02	8.5097+03	7.9019+03
1.78	2.5397+02	4.7141+03	4.6911+03
2.22	1.5440+02	8.6377+03	8.5839+03
2.67	1.1921+02	2.2126+04	2.0770+04
3.11	1.3475+02	3.7305+04	3.4175+04
3.56	9.2979+01	3.6102+04	3.0551+04
4.00	1.1881+02	2.3300+04	2.2480+04
4.44	1.2256+02	3.5093+04	2.9111+04
4.89	1.6529+02	4.3887+04	3.6203+04
5.33	3.7645+02	3.8779+04	3.0067+04
5.78	8.1317+02	2.7905+04	2.1417+04
6.22	1.5921+03	2.4572+04	2.1295+04
6.67	2.4080+03	2.1854+04	2.0369+04
7.11	3.9937+03	1.7792+04	1.7152+04
7.56	5.3633+03	1.3819+04	1.3800+04
8.00	6.7037+03	1.4140+04	1.3918+04
8.44	7.0664+03	1.2863+04	1.2858+04
8.89	7.6815+03	1.2215+04	1.2215+04
9.33	8.0250+03	1.3915+04	1.4303+04
9.78	8.3211+03	1.0741+04	1.0594+04
10.22	8.4996+03	1.0225+04	1.0123+04
10.67	8.3744+03	1.5508+04	1.0334+04
11.11	7.9289+03	1.4570+04	1.1284+04
11.56	7.3821+03	1.0987+04	9.8210+03
12.00	6.8775+03	1.1124+04	9.3455+03
12.44	6.2276+03	1.0178+04	8.8683+03
12.89	5.6572+03	1.0697+04	8.1344+03
13.33	4.9230+03	1.4089+04	1.0312+04
13.78	4.3782+03	1.8191+04	1.3998+04
14.22	3.8911+03	2.7855+04	2.4781+04
14.67	3.4252+03	5.9554+04	4.1527+04
15.11	2.9900+03	6.4836+04	5.3102+04
15.56	2.7332+03	7.5050+04	4.6088+04
16.00	2.3767+03	1.1073+05	4.9320+04
16.44	2.3455+03	8.4741+04	4.4393+04
16.89	2.0375+03	5.9624+04	3.2240+04
17.33	1.9252+03	4.5709+04	2.5132+04
17.78	1.7608+03	2.3016+04	1.3473+04

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
8.5092+02	2.2841+04	1.9924+02	1.5222+04

4.0108-03 5.1945-03 17333 1564 1267 297

EXIT CALLED FROM 024251

TABLE 17 (sheet 54 of 57)

THETA= 9.4785+00 EV = 1.9770+05 DEG R = 1.1000+05 DEG K

GAMMA= 2.9000+04

PRESSURE= 1.0180+06 (DYNE/CM2) = 1.0047+02 (ATM)

RHO= 3.2431-04 (G/CM3) = 2.0247-02 (LB/FT3)

ZBAR= 7.3827+00

UMAX	DELTA U
20.00	.36

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.36	1.6521+03	1.5975+04	1.5077+04
.73	2.5232+02	2.9257+03	2.8211+03
1.09	9.4788+01	3.1863+03	1.5432+03
1.45	5.0490+01	6.1775+03	2.5933+03
1.82	2.4794+01	8.5713+02	4.4194+02
2.18	2.3868+01	1.3681+03	3.8764+02
2.55	1.7051+01	3.3678+03	9.1644+02
2.91	1.6421+01	5.5056+03	1.2034+03
3.27	1.6372+01	6.3592+03	1.8901+03
3.64	1.5491+01	1.1233+04	3.1375+03
4.00	1.8810+01	3.3754+04	5.5794+03
4.36	1.9528+01	3.1979+04	6.0141+03
4.73	1.9247+01	2.4109+04	6.5401+03
5.09	2.3182+01	2.0116+04	6.9027+03
5.45	2.6771+01	1.1898+04	4.8766+03
5.82	4.1709+01	7.1629+03	4.4867+03
6.18	5.8060+01	1.0507+04	6.9028+03
6.55	7.6161+01	1.3154+04	8.6239+03
6.91	1.0324+02	1.5308+04	1.0401+04
7.27	2.7067+02	9.7403+03	9.5941+03
7.64	5.6685+02	1.2378+04	1.1625+04
8.00	7.7550+02	1.0216+04	1.0158+04
8.36	9.1624+02	1.1016+04	1.0003+04
8.73	9.4532+02	1.0078+04	8.5293+03
9.09	8.4459+02	6.3309+03	6.2596+03
9.45	7.4392+02	5.7370+03	5.6228+03
9.82	6.7788+02	1.0305+04	5.4266+03
10.18	6.4774+02	9.5152+03	4.6053+03
10.55	7.7061+02	1.1167+04	4.8299+03
10.91	1.1334+03	1.2416+04	4.4492+03
11.27	1.3942+03	1.5944+04	4.5847+03
11.64	1.6500+03	1.1968+04	4.5443+03
12.00	1.7885+03	2.1767+04	5.5936+03
12.36	1.7814+03	3.2961+04	5.8430+03
12.73	1.7161+03	1.9494+04	4.5435+03
13.09	1.5699+03	1.1713+04	3.3707+03
13.45	1.4673+03	2.7670+04	3.7463+03
13.82	1.3355+03	9.0158+04	6.2389+03
14.18	1.2524+03	1.3396+05	1.0560+04
14.55	1.1410+03	9.6544+04	1.1254+04
14.91	1.0506+03	8.5711+04	1.0211+04
15.27	9.9375+02	6.6828+04	5.4798+03
15.64	9.6601+02	2.4846+04	2.8579+03
16.00	7.7235+02	1.8047+04	2.5040+03
16.36	7.0099+02	1.0560+04	2.2190+03
16.73	9.1239+02	4.2330+03	1.4334+03
17.09	7.3417+02	2.1310+03	1.0072+03
17.45	8.0815+02	4.4967+03	1.0431+03
17.82	8.1574+02	1.5878+03	8.9933+02
18.18	7.2658+02	4.2562+03	9.4960+02
18.55	7.1353+02	4.9856+03	9.3476+02
18.91	6.8497+02	2.7470+03	8.2705+02
19.27	6.3817+02	1.6986+03	8.1266+02
19.64	6.0899+02	1.7880+03	7.6937+02

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
8.2015+01	1.1107+04	2.4141+01	1.8717+03

8.3134-05 1.0382-02 37245 4234 3266 968

TABLE 17 (sheet 55 of 57)

THETA= 9.4785+00 EV = 1.9770+05 DEG R = 1.1000+05 DEG K

GAMMA= 1.4570+04

PRESSURE= 2.0237+08 (DYNE/CM2) = 1.9972+02 (ATM)

RHO= 6.8915-04 (G/CM3) = 4.3024-02 (LB/FT3)

ZBAR= 6.9151+00

UMAX	DELTA U
20.00	.36

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.36	2.9008+03	1.7478+04	1.6789+04
.73	4.3046+02	3.4621+03	3.4442+03
1.09	1.5486+02	4.2273+03	2.2834+03
1.45	8.1843+01	6.5391+03	2.3589+03
1.82	4.0110+01	8.2673+02	8.1536+02
2.18	3.8513+01	1.2742+03	6.0552+02
2.55	2.5821+01	3.5874+03	1.7367+03
2.91	2.6897+01	6.2236+03	2.5284+03
3.27	2.5756+01	7.4832+03	3.4409+03
3.64	1.9925+01	1.1936+04	5.1911+03
4.00	2.7296+01	3.3122+04	9.2179+03
4.36	2.0322+01	3.1194+04	1.0444+04
4.73	2.1775+01	2.6576+04	1.1163+04
5.09	3.3933+01	2.2360+04	1.1409+04
5.45	5.5849+01	1.3011+04	8.0666+03
5.82	1.1227+02	8.8520+03	6.9334+03
6.18	1.7949+02	1.2308+04	9.0801+03
6.55	2.4077+02	1.4144+04	1.0559+04
6.91	3.1292+02	1.5031+04	1.1405+04
7.27	6.7345+02	1.0249+04	1.0191+04
7.64	1.3005+03	1.2920+04	1.2804+04
8.00	1.7612+03	1.0050+04	1.0016+04
8.36	2.0660+03	1.0150+04	9.7006+03
8.73	2.1342+03	1.0928+04	9.1704+03
9.09	1.9153+03	7.0714+03	6.9377+03
9.45	1.6999+03	5.9827+03	5.9722+03
9.82	1.5579+03	8.8236+03	5.7315+03
10.18	1.4449+03	1.0100+04	5.4194+03
10.55	1.4817+03	9.6165+03	5.2414+03
10.91	1.7293+03	9.0131+03	4.9956+03
11.27	1.9189+03	1.2097+04	5.3950+03
11.64	2.2491+03	9.3888+03	5.2596+03
12.00	2.1233+03	1.6629+04	6.4571+03
12.36	2.0181+03	1.9051+04	6.2060+03
12.73	1.8813+03	1.2597+04	4.7130+03
13.09	1.6689+03	1.1189+04	4.0415+03
13.45	1.6076+03	2.1820+04	5.1788+03
13.82	1.4129+03	7.0653+04	8.9528+03
14.18	1.3403+03	1.0972+05	1.5537+04
14.55	1.2242+03	8.8351+04	1.7525+04
14.91	1.1264+03	9.1850+04	1.7694+04
15.27	1.0878+03	7.6195+04	9.1413+03
15.64	9.4785+02	2.7865+04	4.0684+03
16.00	8.6478+02	2.0591+04	3.4140+03
16.36	7.8886+02	1.2649+04	2.9225+03
16.73	9.6975+02	4.0905+03	1.6887+03
17.09	8.0107+02	2.7961+03	1.2025+03
17.45	8.6174+02	3.6000+03	1.1676+03
17.82	8.3216+02	1.2597+03	9.6750+02
18.18	7.5070+02	4.4834+03	1.1631+03
18.55	7.2031+02	5.2908+03	1.1010+03
18.91	7.3882+02	2.3931+03	9.7690+02
19.27	6.6677+02	2.2476+03	1.0185+03
19.64	6.5583+02	1.8650+03	9.6793+02

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
1.6739+02	1.1642+04	3.8011+01	3.0713+03

7.7672-05 8.8421-03 37245 3920 3071 849

TABLE 17 (sheet 56 of 57)

THETA= 9.4785+00 eV = 1.9770+05 DEG R = 1.1000+05 DEG K

GAMMA= 5.8150+03

PRESSURE= 5.0719+08 (DYNE/CM2) = 5.0056+02 (ATM)

RHO= 1.9302-03 (G/CM3) = 1.2050-01 (LB/FT3)

ZBAR= 6.1862+00

UMAX	DELTA U
19.00	.36

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.36	5.8574+03	1.8428+04	1.8208+04
.73	8.5539+02	4.3420+03	4.3224+03
1.09	3.0012+02	5.5615+03	4.3361+03
1.45	1.5673+02	5.5334+03	4.4988+03
1.82	7.7621+01	1.0544+03	1.0478+03
2.18	7.3390+01	2.0536+03	1.7192+03
2.55	4.9562+01	5.4708+03	4.1268+03
2.91	4.4421+01	8.9088+03	6.0579+03
3.27	5.2948+01	1.0094+04	6.7221+03
3.64	3.6660+01	1.5333+04	9.6900+03
4.00	4.6120+01	3.6963+04	1.7162+04
4.36	4.5549+01	3.6232+04	1.9377+04
4.73	5.9029+01	3.0874+04	1.7767+04
5.09	9.9344+01	2.3263+04	1.6836+04
5.45	2.1466+02	1.5304+04	1.3217+04
5.82	4.5800+02	1.2565+04	1.1551+04
6.18	7.3357+02	1.4748+04	1.3149+04
6.55	9.6841+02	1.4724+04	1.3472+04
6.91	1.1585+03	1.3534+04	1.2758+04
7.27	1.8438+03	1.0736+04	1.0707+04
7.64	2.9704+03	1.2050+04	1.2007+04
8.00	3.8206+03	8.9984+03	8.9830+03
8.36	4.3757+03	8.9533+03	8.6955+03
8.73	4.4931+03	1.3577+04	9.3199+03
9.09	4.0705+03	9.3860+03	7.6959+03
9.45	3.6624+03	6.4235+03	6.4172+03
9.82	3.3912+03	6.5121+03	5.9891+03
10.18	3.1096+03	9.4382+03	6.6283+03
10.55	2.9495+03	8.1074+03	6.0967+03
10.91	2.9132+03	8.4663+03	6.2112+03
11.27	2.8976+03	9.8407+03	6.2260+03
11.64	2.9388+03	8.9831+03	7.1041+03
12.00	2.6742+03	1.5791+04	8.7446+03
12.36	2.3821+03	1.3150+04	7.6865+03
12.73	2.1224+03	1.0933+04	6.1656+03
13.09	1.8196+03	2.1286+04	7.1338+03
13.45	1.8365+03	2.8101+04	1.0601+04
13.82	1.5345+03	6.2938+04	1.6386+04
14.18	1.4796+03	9.7360+04	2.5694+04
14.55	1.3464+03	8.7966+04	2.8351+04
14.91	1.2311+03	9.9501+04	3.2019+04
15.27	1.1936+03	7.4540+04	1.5594+04
15.64	1.0495+03	2.4064+04	5.8960+03
16.00	9.7455+02	1.6294+04	4.3329+03
16.36	8.6855+02	1.1278+04	3.6224+03
16.73	9.6495+02	3.6536+03	1.9800+03
17.09	8.7747+02	4.3144+03	1.6423+03
17.45	8.6905+02	2.7172+03	1.4645+03
17.82	8.0816+02	1.1517+03	1.1294+03
18.18	7.3528+02	4.2232+03	1.5260+03
18.55	6.8371+02	4.3138+03	1.4615+03
18.91	8.6955+02	1.9437+03	1.1968+03

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
3.9260+02	1.3552+04	7.9593+01	5.6326+03

5.5018-04 6.6240-03 34405 3145 2538 607

TABLE 17 (sheet 57 of 57)

THETA= 9.4785+00 EV = 1.9770+05 DEG R = 1.1000+05 DEG K

GAMMA= 2.9060+03

PRESSURE= 1.0138+09 (DYNE/CM2) = 1.0006+03 (ATM)

RHO= 4.2071-03 (G/CM3) = 2.6265-01 (LB/FT3)

ZBAR= 5.6793+00

UMAX	DELTA U
18.00	.36

U	CONTINUOUS (CM2/G)	LOCAL PLANCK (CM2/G)	LOCAL ROSSELAND (CM2/G)
.36	9.8954+03	2.1485+04	2.1413+04
.73	1.4139+03	5.5946+03	5.5773+03
1.09	4.9313+02	6.9029+03	5.8347+03
1.45	2.5319+02	4.6111+03	3.8082+03
1.82	1.2816+02	1.7360+03	1.7297+03
2.18	1.1590+02	3.8473+03	3.6612+03
2.55	8.3169+01	8.4802+03	7.2889+03
2.91	6.6684+01	1.1788+04	9.6726+03
3.27	8.7390+01	1.2075+04	9.9789+03
3.64	5.9751+01	1.9032+04	1.4700+04
4.00	7.0542+01	4.0693+04	2.5182+04
4.36	8.7645+01	4.1255+04	2.6860+04
4.73	1.3204+02	3.3364+04	2.3149+04
5.09	2.3122+02	2.4598+04	2.0495+04
5.45	4.6702+02	1.8778+04	1.7451+04
5.82	9.9280+02	1.5642+04	1.5220+04
6.18	1.5477+03	1.6186+04	1.5440+04
6.55	2.0071+03	1.5667+04	1.4916+04
6.91	2.3143+03	1.3476+04	1.3424+04
7.27	3.1515+03	1.1366+04	1.1356+04
7.64	4.4321+03	1.1678+04	1.1669+04
8.00	5.4025+03	9.1875+03	9.1855+03
8.36	6.0367+03	9.5608+03	9.2103+03
8.73	6.1448+03	1.6437+04	1.0008+04
9.09	5.6171+03	1.1886+04	8.8905+03
9.45	5.1102+03	7.4658+03	7.4656+03
9.82	4.7642+03	7.5157+03	7.1817+03
10.18	4.3591+03	9.0650+03	7.7734+03
10.55	4.0424+03	8.5134+03	7.0160+03
10.91	3.7784+03	1.0251+04	7.6575+03
11.27	3.5833+03	1.0392+04	7.9221+03
11.64	3.4163+03	1.0812+04	9.2887+03
12.00	3.0499+03	1.8726+04	1.2608+04
12.36	2.6478+03	1.6625+04	1.2330+04
12.73	2.3363+03	1.5750+04	1.0636+04
13.09	1.9988+03	3.6435+04	1.4350+04
13.45	2.0545+03	4.2709+04	2.1094+04
13.82	1.6977+03	6.5674+04	2.7372+04
14.18	1.6454+03	9.1709+04	3.6966+04
14.55	1.4900+03	8.2704+04	3.7817+04
14.91	1.3965+03	9.0139+04	4.1093+04
15.27	1.2950+03	6.0627+04	1.9757+04
15.64	1.1526+03	1.7778+04	7.0645+03
16.00	1.0701+03	1.0619+04	4.3794+03
16.36	9.6999+02	8.5250+03	3.9283+03
16.73	9.6844+02	3.6274+03	2.3576+03
17.09	1.0093+03	5.5025+03	2.3534+03
17.45	9.0895+02	2.5151+03	1.7914+03
17.82	8.8302+02	1.3621+03	1.3110+03

PLANCK CONT. (CM2/G)	PLANCK MEAN (CM2/G)	ROSSELAND CONT. (CM2/G)	ROSSELAND MEAN (CM2/G)
6.4158+02	1.5658+04	1.3648+02	8.2856+03

9.1586-04 4.9332-03 35475 3314 2832 482

EXIT CALLED FROM 024251

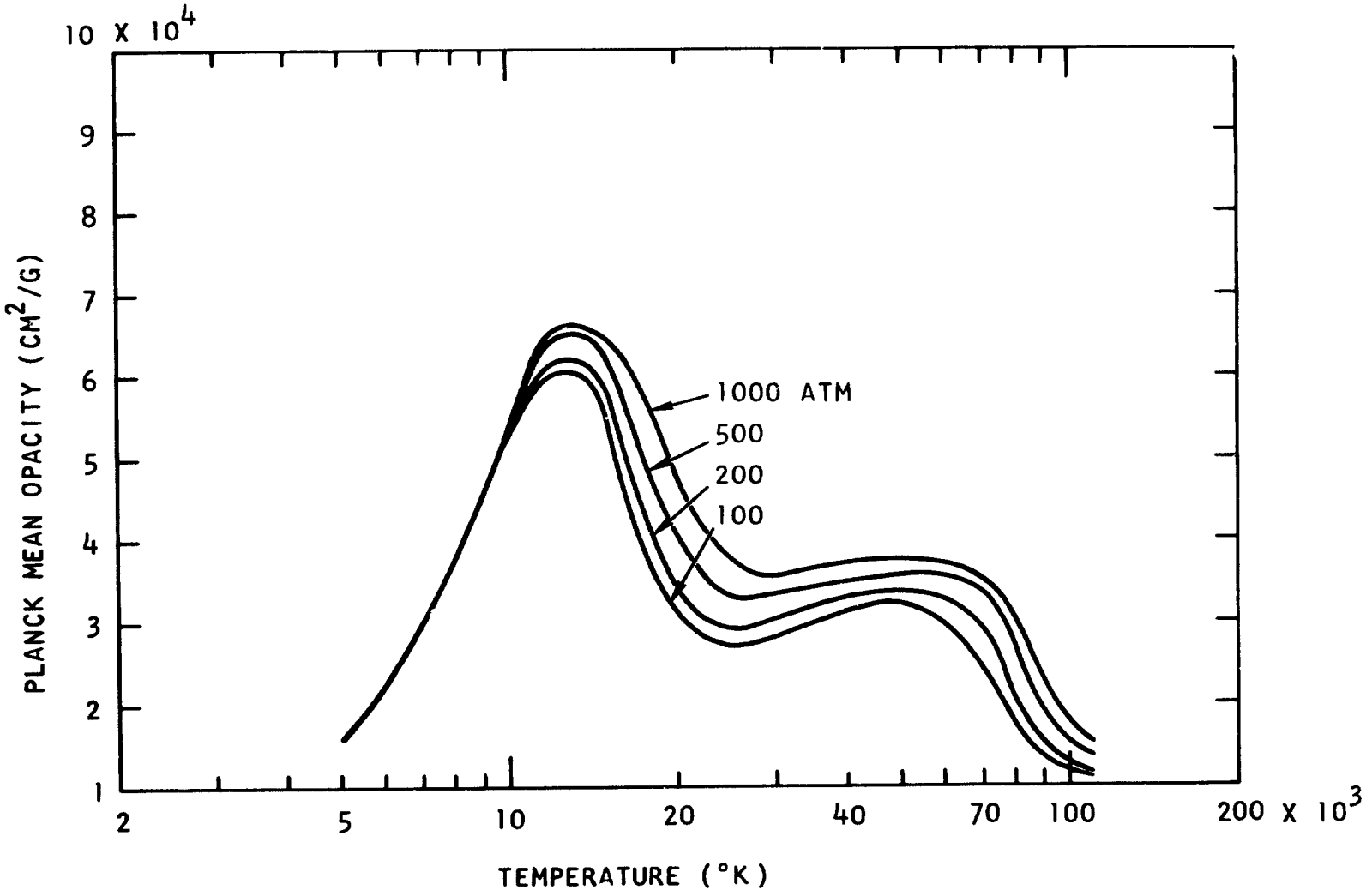


Fig. 3. Planck mean opacity

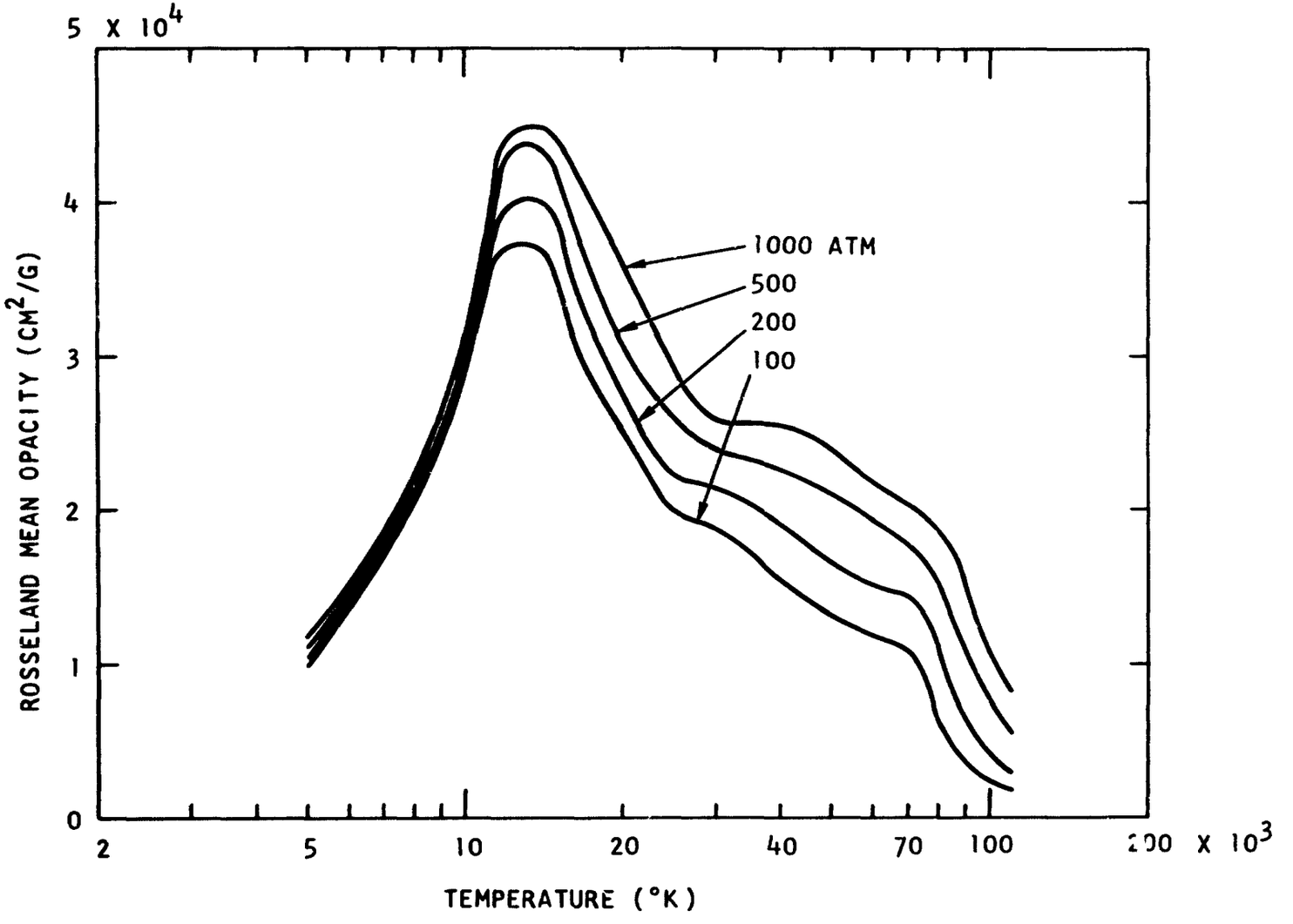


Fig. 4. Rosseland mean opacity

We have also considered the sensitivity of the opacity to uncertainties in the cluster width. For the case $T = 50,000^{\circ}K$ and $P = 100$ atm, we increased the width of all clusters by the factor 1.5. The effect of this change is to increase the overall Rosseland mean opacity by only 13 percent. At isolated frequencies, however, the local Rosseland opacity may be increased by about a factor of three.

6.2. COMPARISON WITH EXPERIMENT

In Figs. 5 and 6 we compare theoretical and experimental values of opacity. The experimental values are inferred from Meggers[24] measurements of the intensity of the line emission from an arc containing one atom of uranium per one thousand atoms of copper.[25] The theoretical values are computed for $T = 5100^{\circ}K$ and $P = 3.58 \times 10^{-4}$ atm.

There are a great many uncertainties in both theory and experiment that could account for quantitative differences between calculated and measured results. We have mentioned some of the theoretical uncertainties in Sec. 1. The results derived from experimental data are based on intensities of observed lines, which number far fewer than the lines actually emitted. In this respect, theoretical values of $\kappa_p(u)$ satisfy expectations in exceeding the values inferred from experimental data. Theory and experiment agree qualitatively in showing two distinct peaks. We expect that the experimental results give an accurate measure of the positions of the peaks on the frequency scale. Thus, the theory should be modified to reproduce this feature of the experimental result.

We computed the curve in Fig. 5 using the eigenvalues and quantum defects as described in Sec. 2.1. In order of increasing frequency, the two peaks in Fig. 5 come from the transitions $7s_{\frac{1}{2}} \rightarrow 7p_{3/2}$, and $7s_{\frac{1}{2}} \rightarrow 7p_{3/2}$, respectively, in the ground configuration $5f^3 7s^2$ in UII, which constitutes 61.9 percent of the ions in the UI-UII plasma. That the peaks are so sharp owes to the narrow cluster width that results from the very high degree of

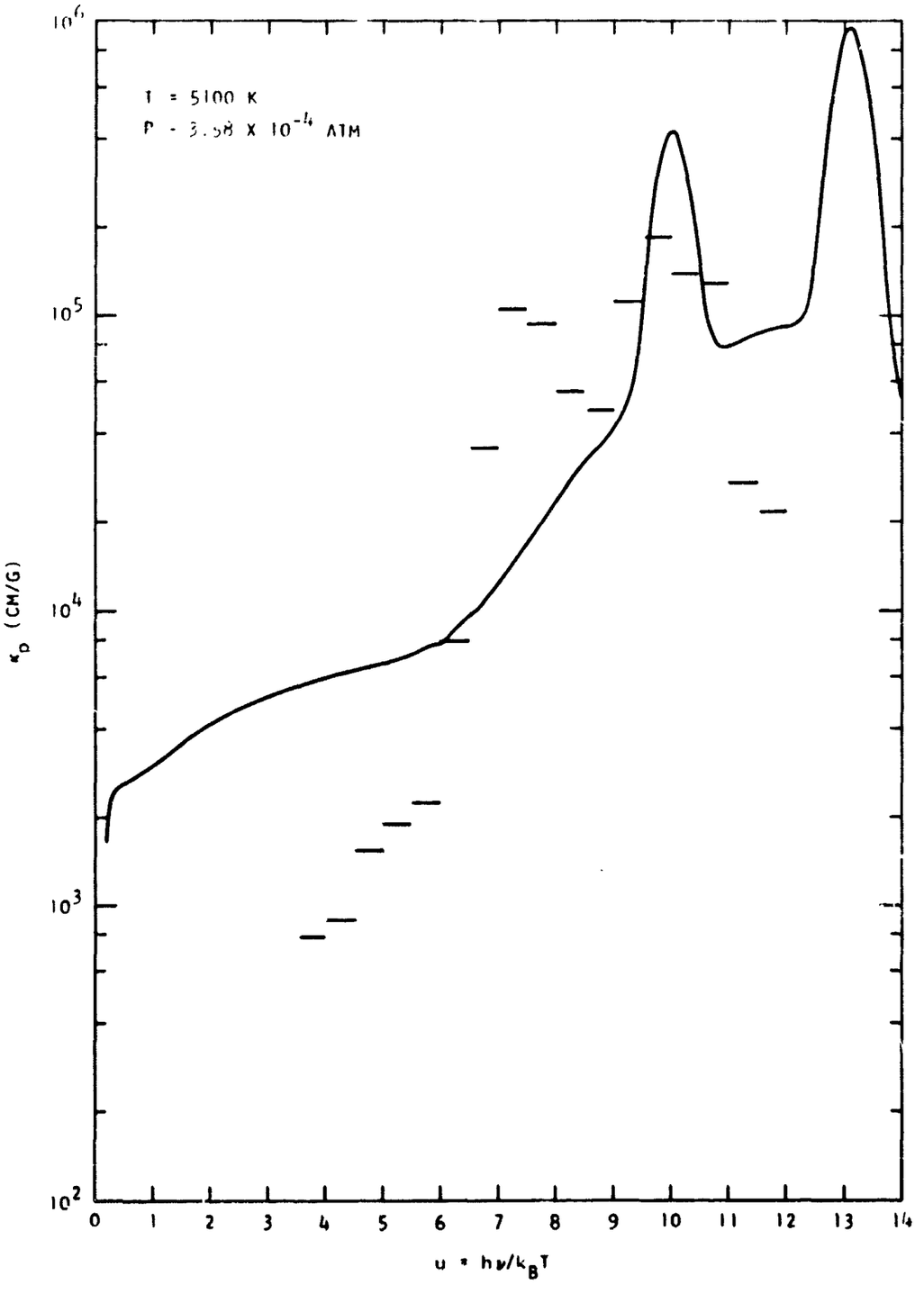


Fig. 5. Theoretical (solid curve) and experimental (——) line opacity; $\epsilon(7s_{\frac{1}{2}})$ = 1.07 Ry

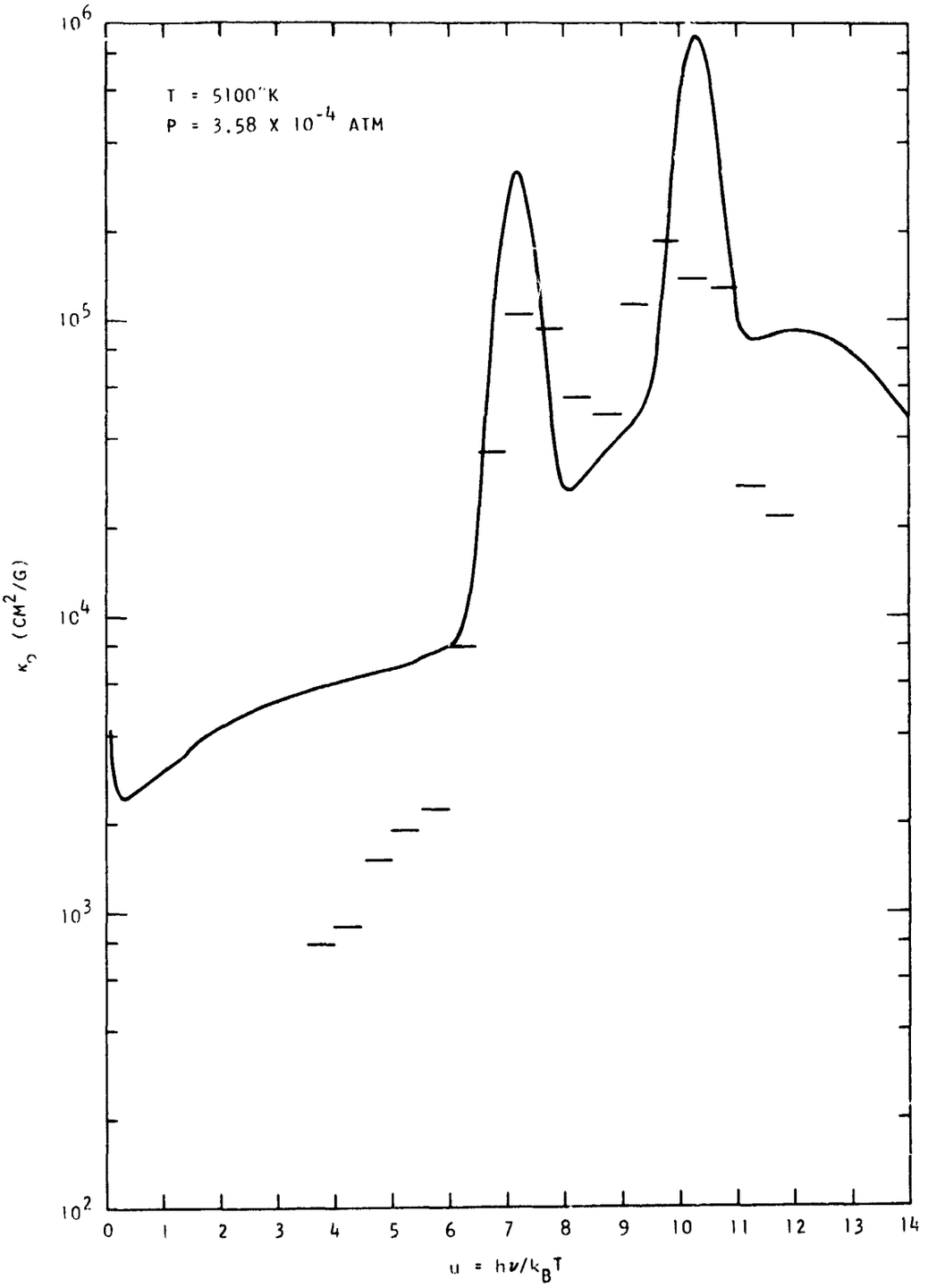


Fig. 6. Theoretical (solid curve) and experimental (——) line opacity; $\epsilon(7s_{\frac{1}{2}}) = 0.98$ Ry

the spherical symmetry in the interaction between the 7s and 5f electrons in UII. By contrast, the same transitions from the ground configuration $5f^3 6d7s^2$ in UI give clusters that are broad by virtue of the large degree of nonspherical symmetry in the interaction between the 7s and 6d electrons. To obtain the curve in Fig. 6, we adjusted the eigenvalue of the $7s_{\frac{1}{2}}$ electron and, correspondingly, the oscillator strengths for transitions out of the $7s_{\frac{1}{2}}$ state, so that the positions of the calculated peaks agree with the measured positions.

6.3. THE EFFECT OF THE BOLTZMANN FACTOR

In calculating the absorption by a transition array, the mean transition energy and dispersion should be determined using a proper Boltzmann weighting of the levels from which the transitions proceed. Instead, we have calculated strength-weighted frequency moments that are independent of temperature and reduce to properly weighted moments only at infinite temperature. Moreover, we have assumed that the total strength of an array is determined only by the population of the subconfiguration from which the transition proceeds. These assumptions should be good approximations only when $= k_B T$ exceeds the mean energy spread of levels in the initial subconfiguration. In practice, it is difficult to develop a generally correct but simple method for calculating moments that properly include the Boltzmann weighting factors. We can, however, get some indication of the magnitude of the considered effect by examining a particular transition array. For this purpose, we choose to study the $3d^3 \rightarrow 3d^2 4p$ transition array in titanium-II. We make this choice because of the almost complete energy-level data for the $3d^3$ and $3d^2 4p$ configurations. Calculations at an infinite temperature T_i and a finite temperature T_f equal to one-third the total splitting of the d^3 configuration yield

$$\langle \epsilon \rangle_{T_i} = 0.2276 \text{ Ry}$$

$$\langle \epsilon \rangle_{T_f} = 0.2715 \text{ Ry}$$

for the mean transition energy and

$$\langle \epsilon^2 \rangle_{T_i} - \langle \epsilon \rangle^2_{T_i} = 0.0081 \text{ Ry}^2$$

$$\langle \epsilon^2 \rangle_{T_f} - \langle \epsilon \rangle^2_{T_f} = 0.00416 \text{ Ry}^2$$

for the mean square deviation of transition energy. The detailed line spectra for the two temperatures are shown in Figs. 7(a) and 7(b).

For the $3d^3 \rightarrow 3d^2 4p$ array in titanium-II the effect of finite temperature is to increase the mean transition energy and to reduce the spread about the mean. We expect the increase in mean transition energy with decreasing temperature to be a general feature of complex transition arrays. To have confidence in any such conclusion, however, would require a more comprehensive study of line absorption in complex atoms.

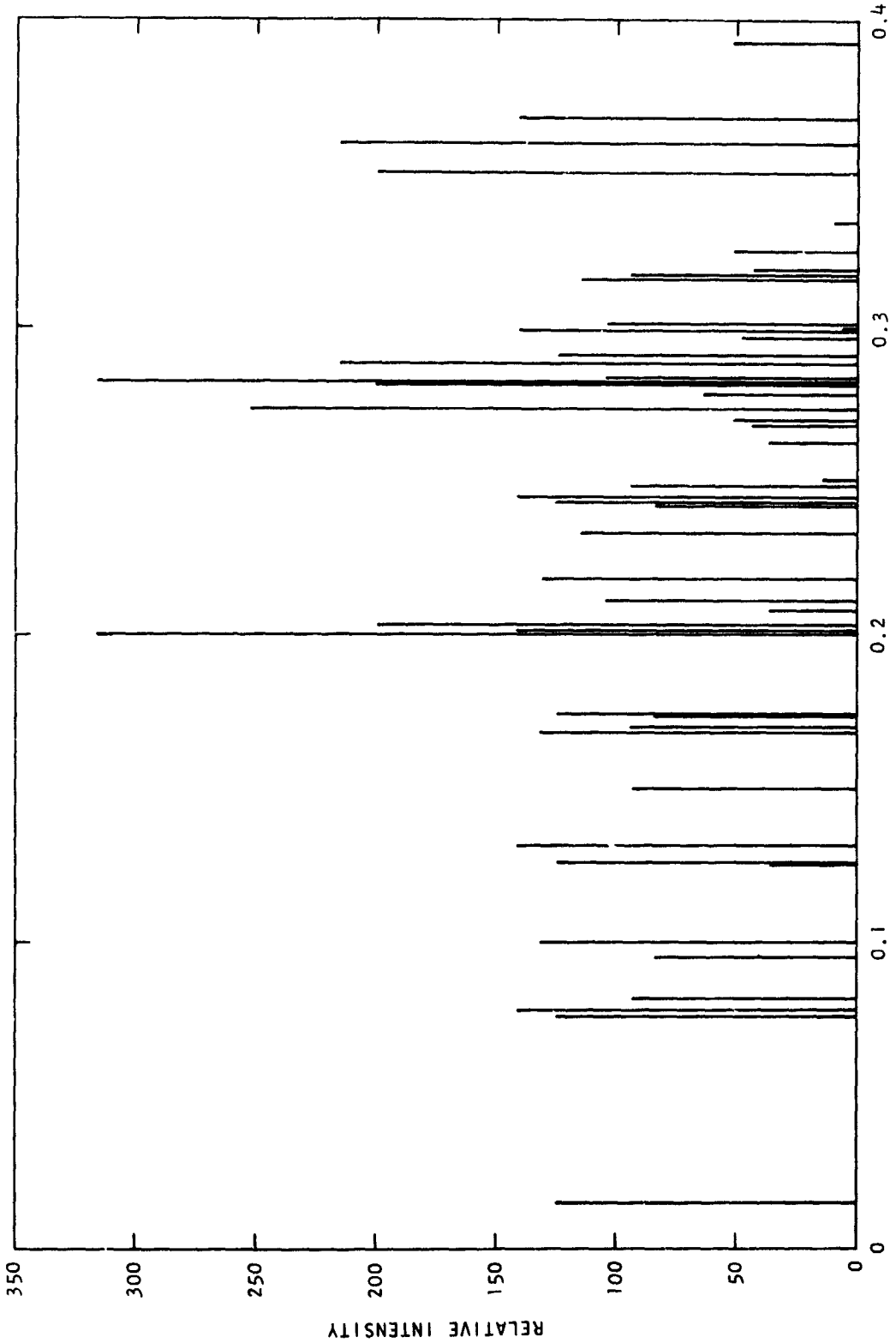


Fig. 7(a). Relative multiplet strength at $T_i = \infty$; energy in Rydbergs

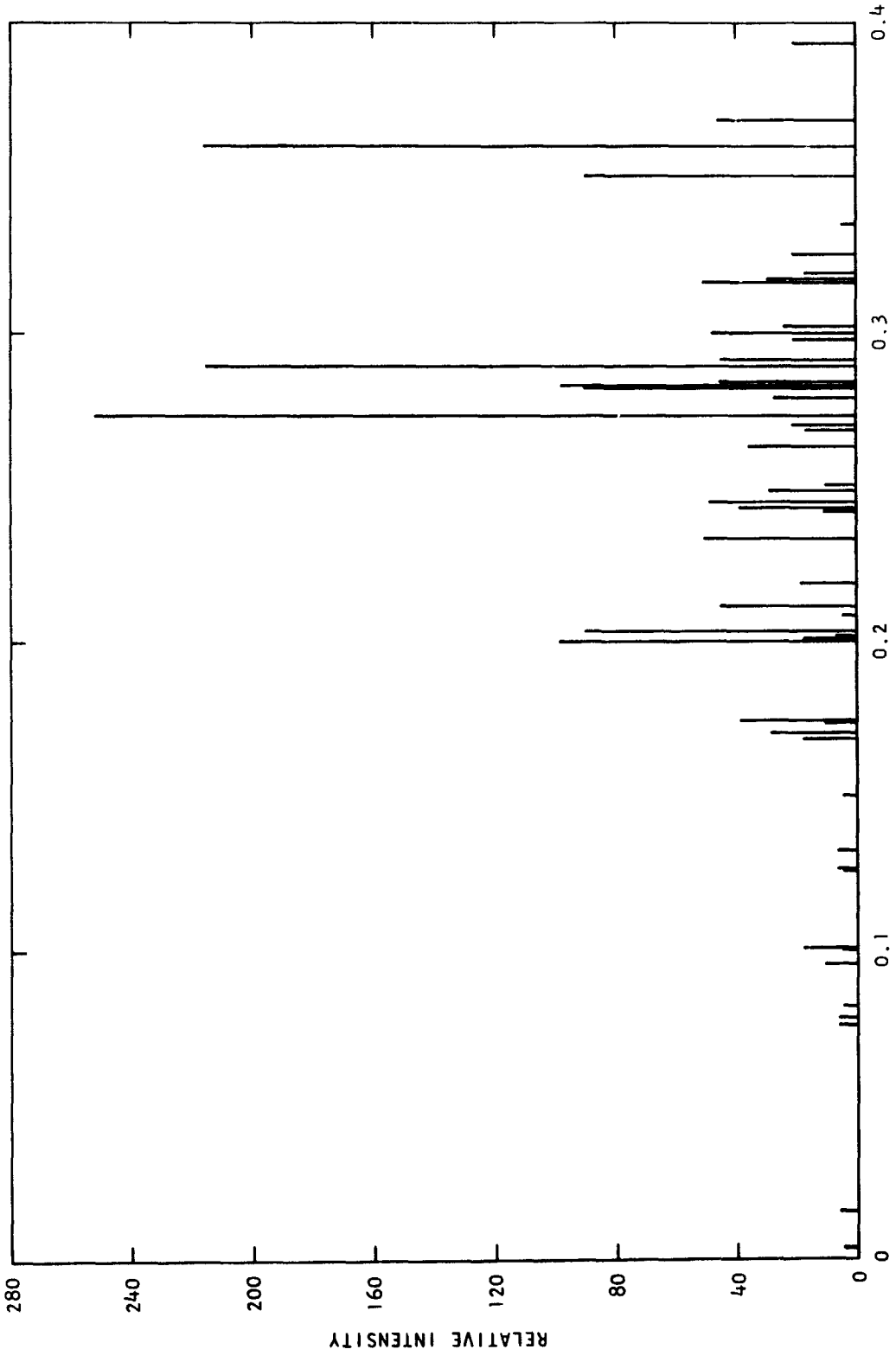


Fig. 7(b). Relative multiplet strength at $T_f = 1/3$ total splitting in d^3; energy in Rydbergs

APPENDIX A

CALCULATION OF THERMODYNAMIC FUNCTIONS AND COMPOSITION

DEFINITIONS

k = net ionic charge (= 0 for UI, = 1 for UII, etc.)

p_k = fractional population of k^{th} ionic species

Γ = free electron degeneracy factor

$$= \frac{2(2\pi m \Theta)^{\frac{3}{2}}}{(N_0/A)\,\rho \bar{z} h^3} \qquad \text{(A-1)}$$

ρ = density

$\bar{z}$ = mean ionic charge = $\sum_k k p_k = n_e/N$

$\Theta = k_B T$

I_k = ionization potential of a free ion with net charge k

I'_k = ionization potential of ion k in plasma

PARTITION FUNCTIONS AND POPULATIONS

We make initial population estimates p_k^0 for specified Θ and Γ using the ionization potentials I_k and setting the electronic partition functions equal to the degeneracy $g_k(1)$ of the ground subconfiguration:

$$p_k^0 = Z_0^{-1} g_k(1) \exp\left[k \ell n\, \Gamma - \sum_{n=1}^{k} (I_{n-1}/\Theta)\right] ,$$

where

$$Z_0 = \sum_k g_k(1) \exp\left[k \ell n\, \Gamma - \sum_{n=1}^{k} (I_{n-1}/\Theta)\right] .$$

Table 18 gives the values of the unlowered ionization potentials I_k used in our calculations. These values were suggested by Patch.[26] (The value for UI is Mann's result;[13] the other values were results of RHFS calculations reported by Waber to Patch in a private communication.)

TABLE 18

IONIZATION POTENTIALS

z'	I (eV)
1	6.11
2	11.46
3	17.94
4	31.14
5	46.03
6	61.82
7	87.93
8	101.1
9	115.0
10	128.9
11	157.9
12	178.5

The p_k^0 provide the starting point for an iteration procedure that gives the composition and thermodynamic functions in the presence of plasma effects and internal states of ionic excitation. As the mathematical basis for iteration we take the Saha equation in the form

$$p_k = \frac{n_k}{N} = \frac{U_k \exp(k\ell n\, \Gamma - \phi_k)}{Z} , \qquad (A-2)$$

where

$$Z = \sum_k U_k \exp(k\ell n\, \Gamma - \phi_k) \quad , \tag{A-3}$$

$$\phi_k = \sum_{j=1}^{k} I'_{j-1}/\Theta \quad , \tag{A-4}$$

and U_k is the electronic partition function for the k^{th} ion. We introduce

$$s = \bar{z} + \overline{z^2} \tag{A-5}$$

and calculate the pressure-lowered ionization potential from

$$I'_j = I_j - (j/\bar{z})J\Theta \quad , \tag{A-6}$$

where

$$\bar{J}/\bar{z} = H(s) \qquad s \geq s_0$$
$$= H(s_0) \qquad s < s_0$$

$$H(s) = \frac{1}{2s}\left[\left(3s\,\frac{e^2}{D\Theta} + 1\right)^{\frac{2}{3}} - 1\right] \tag{A-7}$$

and s_0 is a parameter at our disposal. In the calculation we have taken $s_0 = 2$. The introduction of s_0 is the ad hoc device by means of which we avoid the difficulties that we may encounter when $\bar{z}$ is small (see Sec. 3. 1).

The partition function U_k follows from the equations of Sec. 3. 2. The summation in the equations for U^0 include only those subconfigurations in which the unperturbed binding energy of every electron is greater than the lowering produced by pressure effects:

$$|\epsilon_k(\{N_i\})| > \frac{k+1}{\bar{z}}\,\frac{\bar{J}\Theta}{Ry} \quad . \tag{A-8}$$

Similarly, we limit the sum in Eq. (74) for U_k^{ex} by the condition

$$|\epsilon_k(i)| < \frac{k+1}{\bar{z}}\,\frac{\bar{J}\Theta}{Ry} \quad . \tag{A-9}$$

We express U_k^E as

$$U_k^E = U_k^H + \sum_{i=1}^{5} g_i U_k^i \quad , \tag{A-10}$$

where U_k^H is the contribution from states with $\ell \geq 4$; U_k^i, $i = 1, \ldots 5$ is the contribution from $s_{\frac{1}{2}}$, $p_{\frac{1}{2}}$, $p_{\frac{3}{2}}$, d, and f states, respectively; and the g_i are the corresponding degeneracies ($g_1 = 2$, $g_2 = 2$, $g_3 = 4$, $g_4 = 10$, $g_5 = 14$). Explicitly,

$$U_k^H = \sum_{m=5}^{\bar{n}_k} (2m^2 - 32) \exp(n_{0,k}^2/m^2) \tag{A-11}$$

$$U_k^i = \sum_{m=n_{\min,k}(i)}^{\bar{n}_k(i)} \exp\{n_{0,k}^2/[m - \mu_k(i)]^2\} \quad , \tag{A-12}$$

where the $\mu_k(i)$ are asymptotic quantum defects for the k^{th} ion. Here

$$n_{0,k}^2 = (k+1)^2 \frac{Ry}{\mathcal{H}} \quad , \tag{A-13}$$

$$\bar{n}_k = \text{int}\left[\frac{(k+1)}{\bar{J}} \bar{z} \frac{Ry}{\mathcal{H}}\right] \quad , \tag{A-14}$$

$$\bar{n}_k(i) = \bar{n}_k + \mu_k(i) \quad , \tag{A-15}$$

and int[...] means the integer part of [...]. The lower limit $n_{\min,k}(i)$ is the smallest principal quantum number that an E-electron may have in the angular momentum state i in ion k. Table 19 lists the values of $n_{\min,k}(i) = n_{\min}(z', I)$ used in our calculations. One-electron states with principal quantum number n greater than $\bar{n}_k$ or $\bar{n}_k(i)$ in the k^{th} ion are pressure-ionized. If $\bar{n}_k$ ($\bar{n}_k(i)$) is less than 5 ($n_{\min,k}(i)$), U_k^H (U_k^i) vanishes.

The sum in Eq. (A-11) may involve an inconveniently large number of terms. In that case, we approximate the sum over terms with $m >> 1$

TABLE 19

CONTROL QUANTUM NUMBERS USED IN PROGRAM

$n_{min}(z', I)$

z'	I: $s_{1/2}$	$p_{1/2}$	$p_{3/2}$	d	f	g
1	8	7	7	7	6	
2	↓	↓	↓	↓	↓	
3	↓	↓	↓	↓	↓	
4	7	↓	↓	↓	↓	
5	↓	↓	↓	↓	↓	
6	↓	↓	↓	6	↓	
7	↓	↓	↓	↓	↓	
8	↓	↓	↓	↓	↓	
9	↓	↓	↓	↓	↓	
10	↓	↓	↓	↓	↓	
11	↓	↓	↓	↓	↓	
12	↓	↓	↓	↓	↓	

$n'_e(z', I)$

z'	I: $s_{1/2}$	$p_{1/2}$	$p_{3/2}$	d	f	g
1	7	7	7	6	5	5
2	↓	↓	↓	↓	↓	↓
3	↓	↓	↓	↓	↓	↓
4	↓	↓	↓	↓	↓	↓
5	↓	↓	6	↓	↓	↓
6	↓	6	↓	↓	↓	↓
7	↓	↓	↓	↓	↓	↓
8	↓	↓	↓	↓	↓	↓
9	↓	↓	↓	↓	↓	↓
10	↓	↓	↓	↓	↓	↓
11	↓	↓	↓	↓	↓	↓
12	↓	↓	↓	↓	↓	↓

$n_c(z', I)$

z'	I: $s_{1/2}$	$p_{1/2}$	$p_{3/2}$	d	f	g
1	7	6	6	6	5	5
2	↓	↓	↓	↓	↓	↓
3	↓	↓	↓	↓	↓	↓
4	↓	↓	↓	↓	↓	↓
5	6	↓	↓	↓	↓	↓
6	↓	↓	↓	↓	↓	↓
7	↓	↓	↓	↓	↓	↓
8	↓	↓	↓	↓	↓	↓
9	↓	↓	↓	↓	↓	↓
10	↓	↓	↓	↓	↓	↓
11	↓	↓	↓	↓	↓	↓
12	↓	↓	↓	↓	↓	↓

$n_F(z', I)$

z'	I: $s_{1/2}$	$p_{1/2}$	$p_{3/2}$	d	f	g
1	6	6	6	5	4	0
2	↓	↓	↓	↓	↓	↓
3	↓	↓	↓	↓	↓	↓
4	↓	↓	↓	↓	↓	↓
5	↓	↓	5	↓	↓	↓
6	↓	5	↓	↓	↓	↓
7	↓	↓	↓	↓	↓	↓
8	↓	↓	↓	↓	↓	↓
9	↓	↓	↓	↓	↓	↓
10	↓	↓	↓	↓	↓	↓
11	↓	↓	↓	↓	↓	↓
12	↓	↓	↓	↓	↓	↓

$n_{as}(z', I)$

	I: $s_{1/2}$	$p_{1/2}$	$p_{3/2}$	d	f	g
1-12	8	8	8	8	8	8

by an integral. More specifically, the terms with $m \leq 10$ are calculated term by term, whereas for the remaining part of the sum we make the approximation

$$\sum_{m=11}^{\bar{n}_k} (2m^2 - 32) \exp(n_{0,k}^2/m^2) \approx \int_{21/2}^{\bar{n}_k} (2x^2 - 32) \exp(n_{0,k}^2/x^2)\, dx \quad \text{(A-16)}$$

$$\approx Q(\bar{n}_k, n_{0,k}) - Q\left(\frac{21}{2}, n_{0,k}\right) . \quad \text{(A-17)}$$

The result

$$Q(x, y) = \tfrac{2}{3} x^3 + 2x(y^2 - 16) \quad \text{(A-18)}$$

follows on expanding the exponent in Eq. (A-16) and retaining the leading terms. It is not very difficult to verify that the approximations (A-16) and (A-17) are poor ones only when the terms with $m > 10$ make a relatively small contribution to U_k^H, in which case the approximation also makes a relatively small contribution.

We apply similar considerations to the calculation of $U_k^{(i)}$. In this case

$$\sum_{m=11}^{\bar{n}_k(i)} \exp\{n_{0,k}^2/[m - \mu_k(i)]^2\} \cong H(\bar{n}_k, n_{0,k}) - H\left[\frac{21}{2} - \mu_k(i), n_{0,k}\right] , \quad \text{(A-19)}$$

where

$$H(x, y) = x - y^2/x . \quad \text{(A-20)}$$

We can now calculate the full electronic partition function U_k. The fractional populations follow from Eqs. (A-2) and (A-3), and the thermodynamic functions follow without further difficulty.

INTERNAL ENERGY

The specific internal energy E follows from

$$E = \frac{\partial(\beta F)}{\partial \beta} \quad , \tag{A-21}$$

where

$$\beta = \Theta^{-1}$$

and F is given by Eq. (41) with $N_k = p_k N_0/A$, where $N = N_0/A$ = Avogadro's number/atomic number = number of nuclei per unit mass of material. We express E in the form

$$E = E_{kin} + E_{ion} + E_{ex} + E_p \quad ,$$

where E_{kin} is the kinetic energy of free translation, E_{ion} is the ionization energy in the absence of plasma effects, E_{ex} is the electronic excitation energy, and E_p is the plasma energy:

$$E_{kin} = \tfrac{3}{2} \frac{N_0}{A} (1 + \bar{z}) \Theta \tag{A-22}$$

$$E_{ion} = \frac{N_0}{A} \sum_k p_k \sum_{j=1}^{k} I_{j-1} \tag{A-23}$$

$$E_{ex} = \frac{N_0}{A} \sum p_k E_{ex,\,k} \tag{A-24}$$

$$E_p = -\tfrac{1}{2} \frac{N_0}{A} (1 + z^*) \bar{J} \Theta \quad . \tag{A-25}$$

The quantity $E_{ex,\,k}$ is the electronic excitation energy of the k^{th} ion measured from a zero energy corresponding to the ground state of the ion:

$$E_{ex,\,k} = -U_k^{-1} \frac{\partial U_k}{\partial \beta} = -U_k^{-1} U_{k,\,\beta} \quad . \tag{A-26}$$

DENSITY

$$\rho = 0.010125 \frac{[\Theta(eV)]^{\frac{3}{2}}}{\Gamma} A/\bar{z} \quad \text{gm cm}^{-3} \tag{A-27}$$

PRESSURE

$$P = -F_v = -\left(\frac{\partial F}{\partial v}\right)_\theta , \tag{A-28}$$

where $v = 1/\rho$ is the specific volume. Neglecting the volume dependence of the electronic partition function, but including the plasma effect, we can write

$$P = P_{kin} + P_p , \tag{A-29}$$

where

$$P_{kin} = \frac{N_0}{A} \rho(1 + \bar{z})\Theta \tag{A-30}$$

and

$$P_p = \tfrac{1}{3} \rho E_p . \tag{A-31}$$

ENTHALPY

$$W = E + \frac{P}{\rho} . \tag{A-32}$$

HELMHOLTZ FREE ENERGY

We separate the plasma contribution to F and write

$$F = F_0 + F_p , \tag{A-33}$$

where

$$F_0 = \frac{N_0}{A} \Theta \left[11.56882 + \tfrac{3}{2} \ln A + \bar{z}(1 + \ln \Gamma) + \ln(\bar{z}\,\Gamma) - \sum_k p_k \left(\ln \frac{p_k}{U_k} + \frac{1}{\Theta} \sum_{j=0}^{k-1} I_j \right) \right] . \tag{A-34}$$

From Eq. (59),

$$F_p = -\tfrac{1}{2}\frac{N_0}{A}\Theta G(x) \ , \tag{A-35}$$

where

$$G(x) = x + \tfrac{1}{2}x^2 - \tfrac{1}{2}\ln\left[\frac{1 + (1+x) + (1+x)^2}{3}\right] + \frac{1}{\sqrt{3}}\left[\tan^{-1}\frac{2(1+x)+1}{\sqrt{3}} - \frac{\pi}{3}\right] \tag{A-36}$$

and

$$x = \left(1 + 3\,s\,\frac{e^2}{D\Theta}\right)^{\frac{1}{3}} - 1 \ . \tag{A-37}$$

For $s < s_0$ we set

$$x = \left(1 + 3\,s_0\,\frac{e^2}{D\Theta}\right)^{\frac{1}{3}} - 1 \qquad s < s_0 \ . \tag{A-38}$$

ENTROPY

$$S = (E - F)/\Theta \ . \tag{A-39}$$

SPECIFIC HEAT AT CONSTANT VOLUME

$$C_v = E_\theta = \left(\frac{\partial E}{\partial \Theta}\right)_v$$

$$= \frac{N_0}{A}\left[\tfrac{3}{2}(1 + \bar{z}) + \tfrac{3}{2}\Theta\bar{z}_\theta + \sum_k p_k E_{ex,\,k,\,\theta} + \sum_k p_{k,\,\theta}\left(E_{ex,\,k} + \sum_{j=0}^{k-1} I_j\right)\right] + E_{p,\,\theta} \ . \tag{A-40}$$

SPECIFIC HEAT AT CONSTANT PRESSURE

$$C_p = \left(\frac{\partial W}{\partial \Theta}\right)_P$$

$$= C_v + E_v\left(\frac{\partial v}{\partial \Theta}\right)_P + P\left(\frac{\partial v}{\partial \Theta}\right)_P \ . \tag{A-41}$$

TEMPERATURE AND VOLUME DERIVATIVES OF THERMODYNAMIC QUANTITIES

To determine C_p and C_v we must calculate temperature and volume derivatives of p_k, $E_{ex,k}$, and E_p. For temperature derivatives, we have

$$E_{ex,k,\theta} = \beta^2\left[\frac{U_{k,\beta,\beta}}{U_k} - \left(\frac{U_{k,\beta}}{U_k}\right)^2\right] . \tag{A-42}$$

If we neglect the temperature dependence associated with the cutoff of the sum over states, the calculation of $U_{k,\beta}$ and $U_{k,\beta,\beta}$ is straightforward and requires no further discussion. The temperature derivative of the plasma energy at constant volume is

$$E_{p,\theta} = -\frac{1}{2}\frac{N_0}{A}\Theta[s(fs_\theta + g_\theta) + Fs_\theta] + \frac{E_p}{\Theta} . \tag{A-43}$$

Setting

$$F = \bar{J}/\bar{z} , \tag{A-44}$$

we have

$$\begin{aligned} f &= -\frac{F}{s} + \frac{3}{2}\frac{(x+1)^{-1}}{s}\frac{e^2}{D\Theta} \qquad s \geq s_0 \\ &= -\frac{F}{s_0} + \frac{3}{2}\frac{(x+1)^{-1}}{s_0}\frac{e^2}{D\Theta} \qquad s < s_0 . \end{aligned} \tag{A-45}$$

and g_θ is given by Eq. (A-54) below. To obtain C_v we require E_v and $(\partial v/\partial\Theta)_P$. Neglecting the volume dependence of the electronic partition function

$$E_{kin,v} = \frac{3}{2}\frac{N_0}{A}\bar{z}_v\Theta , \tag{A-46}$$

$$E_{ion,v} = \frac{N_0}{A}\sum_k p_{k,v}\left(\sum_{j=0}^{k-1} I_j\right) , \tag{A-47}$$

$$E_{ex,\,v} = \frac{N_0}{A} \sum_k p_{k,\,v} E_{ex,\,k} \quad , \tag{A-48}$$

$$E_{p,\,v} = -\frac{1}{2} \frac{N_0}{A} \Theta [F s_v + s(f s_v + g_v)] \quad , \tag{A-49}$$

$$g_v = -\frac{1}{2} \rho \frac{e^2}{D\Theta} (1 + x)^{-1} \quad , \tag{A-50}$$

$$\left(\frac{\partial v}{\partial \Theta}\right)_P = \left(P - \frac{N_0}{A} \Theta \bar{z}_v - \tfrac{1}{3} E_{p,\,v}\right)^{-1} \left[\frac{N_0}{A}(1 + \bar{z} + \Theta \bar{z}_\theta) + \tfrac{1}{3} E_{p,\,\theta}\right] \quad . \tag{A-51}$$

The population derivatives follow from differentiation of the Saha equation (A-2); we find

$$f_{k,\,\theta} = p_k \left[\left(1 - \frac{k}{\bar{z}}\right) \bar{z}_\theta + R_{k\theta} - \sum p_k R_{k\theta} \right.$$

$$\left. + \frac{1}{2}(f s_\theta + g_\theta)(k^2 + k - \bar{z} - \bar{z}^2)\right] \quad , \tag{A-52}$$

where

$$R_{k\theta} = \frac{3}{2} k\beta + \beta^2 \left(\sum_{j=0}^{k-1} I_j + E_{ex,\,k}\right) \tag{A-53}$$

$$g_\theta = -\frac{3}{2\Theta} \frac{e^2}{D\Theta} (1 + x)^{-1} \quad . \tag{A-54}$$

We now derive a pair of equations for $\bar{z}_\theta$ and s_θ. Multiplying Eq. (A-52) first by k and summing over k, and then by k(k + 1) and performing the sum gives

$$\left.\begin{aligned} a_{1\theta} \bar{z}_\theta + a_{2\theta} s_\theta &= a_{3\theta} \quad , \\ b_{1\theta} \bar{z}_\theta + b_{2\theta} s_\theta &= b_{3\theta} \quad , \end{aligned}\right\} \tag{A-55}$$

where

$$a_{1\theta} = -1 + \overline{z} - z^{*} \quad , \tag{A-56}$$

$$a_{2\theta} = \tfrac{1}{2}f\left(\overline{z^3} + \overline{z^2} - \overline{z}\,\overline{z^2} - \overline{z}^2\right) \quad , \tag{A-57}$$

$$a_{3\theta} = \overline{z}\left[\sum_k p_k R_{k\theta} + \tfrac{1}{2}g_\theta\left(\overline{z^2} + \overline{z}\right) - \sum k\, p_k R_{k\theta} - \tfrac{1}{2}g_\theta\left(\overline{z^3} + \overline{z^2}\right)\right], \tag{A-58}$$

$$b_{1\theta} = \overline{z} + \overline{z^2} - \left(\overline{z^3} + \overline{z^2}\right)/\overline{z} \quad ,$$

$$b_{2\theta} = -1 - \tfrac{1}{2}f\left(\overline{z} - \overline{z^4} - 2\overline{z^3}\right) \quad ,$$

$$b_{3\theta} = \left(\overline{z} + \overline{z^2}\right)\left[\sum p_k R_{k\theta} + \tfrac{1}{2}g_\theta\left(\overline{z^2} + \overline{z}\right) - \sum p_k k(k+1) R_{k\theta} - \frac{g_\theta}{2}\left(\overline{z^4} + 2\overline{z^3} + \overline{z^2}\right)\right],$$

and $\overline{z^n}$ is calculated from

$$\overline{z^n} = \sum p_k k^n \quad .$$

Finally, we get $\overline{z}_\theta$, s_θ from Eq. (A-55) and $p_{k,\theta}$ from Eq. (A-52). Similarly,

$$p_{k,v} = p_k\left[\overline{z}_v - \rho\overline{z} + k\rho - k\overline{z}_v/\overline{z} + \tfrac{1}{2}(s_v f + g_v)\left(k^2 + k - \overline{z^2} - \overline{z}\right)\right] \quad , \tag{A-59}$$

$$g_v = -\tfrac{1}{2}\rho\,\frac{e^2}{D\circledR}\,(1+x)^{-1} \quad , \tag{A-60}$$

$$a_{1v}\overline{z}_v + a_{2v}s_v = a_{3v} \quad , \tag{A-61}$$

$$b_{1v}\overline{z}_v + b_{2v}s_v = b_{3v} \quad , \tag{A-62}$$

$$a_{1v} = -1 - \left(\overline{z^2} - \bar{z}^2\right)/\bar{z} \ , \tag{A-63}$$

$$a_{2v} = \tfrac{1}{2}f\left(\overline{z^3} + \overline{z^2} - \bar{z}^2 - \bar{z}\,\overline{z^2}\right) \ , \tag{A-64}$$

$$a_{3v} = -\tfrac{1}{2}g_v\left(\overline{z^3} + \overline{z^2} - \bar{z}^2 - \bar{z}\,\overline{z^2}\right) - \rho\left(\overline{z^2} - \bar{z}^2\right) \ , \tag{A-65}$$

$$b_{1v} = \bar{z} + \overline{z^2} - \left(\overline{z^3} + \overline{z^2}\right)/\bar{z} \ , \tag{A-66}$$

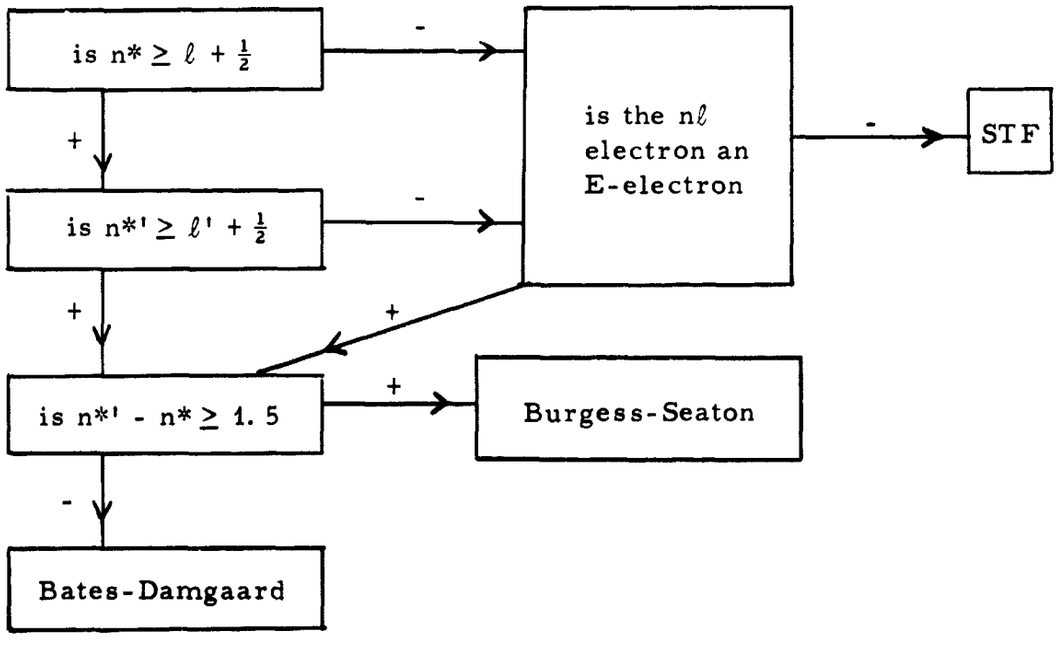
$$b_{2v} = -1 + \tfrac{1}{2}f\left[\overline{z^4} + 2\overline{z^3} + \overline{z^2} - \left(\bar{z} + \overline{z^2}\right)^2\right] \ , \tag{A-67}$$

$$b_{3v} = -\tfrac{1}{2}g_v\left[\overline{z^4} + 2\overline{z^3} + \overline{z^2} - \left(\bar{z} + \overline{z^2}\right)^2\right] - \rho\left(\overline{z^3} + \overline{z^2} - \bar{z}^2 - \bar{z}\,\overline{z^2}\right) \ . \tag{A-68}$$

APPENDIX B

CALCULATION OF BOUND-BOUND, BOUND-FREE, AND FREE-FREE TRANSITIONS

We obtain σ_{ij}^2 from either the STF tables, the Bates-Damgaard tables,[27] the Burgess-Seaton tables,[28] or by means of Kramers' theory. Which of these applies for bound-bound transitions depends on ℓ and ℓ' and the values of the effective principal quantum numbers n* and n*' of the jumping electron in the initial and final state respectively. The tables are entered according to the following scheme for absorptions by an s, p, or d electron and for nf → n'd transitions.



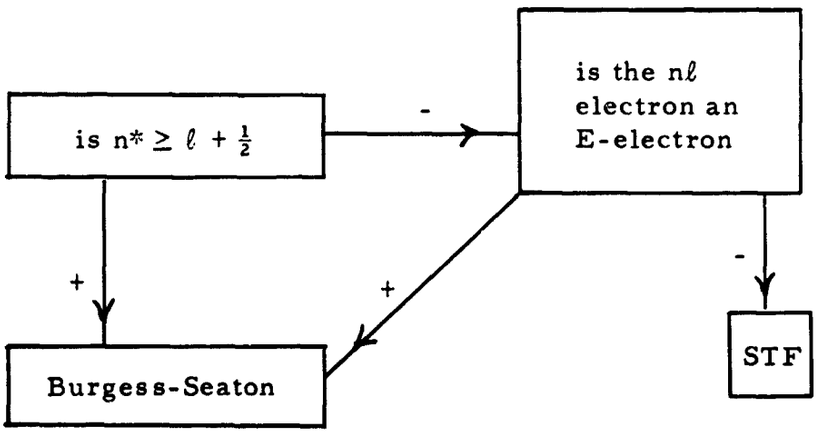
Here we have made use of the observation that σ_{ij}^2 for bound-bound transitions can be accurately obtained from the Burgess-Seaton table when $n^{*\prime} - n^* \geq 1.5$. The connection between r_{ij} and the Burgess-Seaton tables is given in Eq. (B-10).

For (1) $5f \rightarrow n'g$ transitions, we enter the STF tables;

(2) $nf \rightarrow n'g$ transitions, $g \rightarrow f$ transitions, and $\ell \geq 4 \rightarrow \ell' \geq 4$ transitions, we use Eq. (B-8).

When we require STF wave functions we enter Table 20 if $n' \leq 7$, but we obtain σ_{ij}^2 from the STF bound-free tables when $n' \geq 8$. The connection between the bound-free tables and σ_{ij}^2 for bound-bound transitions is contained in Eq. (B-20).

For bound-free absorptions by an s, p, or d electron and for $nf \rightarrow kd$ transitions, we enter the tables for σ_{ij} according to the following scheme:



For (1) $5f \rightarrow kg$ transitions we enter the STF tables;

(2) $nf \rightarrow kg$ transitions, $ng \rightarrow kf$ transitions, and $\ell \geq 4 \rightarrow k\ell' \geq 4$ transitions, we use Eq. (B-17).

TABLE 20

SLF BOUND-BOUND a_{ij}^2

i	j	a_{ij}^2	i	j	a_{ij}^2	i	j	a_{ij}^2
	$z' = 1$			$z' = 2$			$z' = 3$	
5s1/2	7p1/2	5.799-04	5s1/2	7p1/2	5.791-04	5s1/2	7p1/2	7.819-04
	7p3/2	1.077-04		7p3/2	1.057-04		7p3/2	1.745-04
6s1/2	7p1/2	1.469-02	6s1/2	7p1/2	1.351-04	6s1/2	7p1/2	1.608-02
	7p3/2	4.853-04		7p3/2	2.246-04		7p3/2	3.367-04
5p1/2	7s1/2	1.271-03	5p1/2	7s1/2	1.226-03	5p1/2	7s1/2	1.429-03
	7d3/2	1.529-06		6d3/2	3.322-06		6d3/2	1.205-07
6p1/2	7s1/2	1.506-01		7d3/2	4.657-06		7d3/2	1.387-05
	7d3/2	2.078-04	6p1/2	7s1/2	1.421-01	6p1/2	7s1/2	1.599-01
5p3/2	7s1/2	2.296-03		6d3/2	1.218-01		6d3/2	1.290-01
	5d3/2	3.777-02		7d3/2	1.197-03		7d3/2	1.551-03
	6d3/2	2.115-04	5p3/2	7s1/2	2.349-03	5p3/2	7s1/2	2.618-03
	7d3/2	1.364-05		6d3/2	2.805-04		6d3/2	3.924-04
6p3/2	7s1/2	4.044-01		7d3/2	5.829-05		7d3/2	1.369-04
	5d3/2	9.063-03	6p3/2	7s1/2	3.893-01	6p3/2	7s1/2	4.221-01
	6d3/2	1.757-01		6d3/2	1.878-01		6d3/2	1.944-01
	7d3/2	2.294-06		7d3/2	6.458-05		7d3/2	5.200-07
5d3/2	7p1/2	3.097-04	5d3/2	6p1/2	1.561-02	5d3/2	7p1/2	4.538-04
	7p3/2	2.659-04		7p1/2	3.863-04		7p3/2	4.821-04
	5f5/2	1.869 02		6p3/2	8.191-03		5f5/2	1.882-02
	6f5/2	3.643-08		7p3/2	3.505-04		6f5/2	1.526-05
	7f5/2	8.824-09		5f5/2	1.859-02		7f5/2	4.730-06
6d3/2	7p1/2	4.728-01		6f5/2	3.225-06	6d3/2	7p1/2	3.008-01
	7p3/2	4.011-01		7f5/2	2.427-07		7p3/2	2.352-01
	5f5/2	2.801-02	6d3/2	6p1/2	1.218-01		5f5/2	3.099-02
	6f5/2	4.353-03		7p1/2	3.436-01		6f5/2	6.894-02
	7f5/2	3.256-03		6p3/2	1.877-01		7f5/2	2.640-02
5f5/2	5d3/2	1.869-02		7p3/2	2.717-01	5f5/2	6d3/2	3.099-02
	6d3/2	2.801-02		5f5/2	2.444-02		7d3/2	2.013-05
	7d3/2	2.178-05	5f5/2	5d3/2	1.859-02	5d5/2	5g7/2	1.799-04
	5g	1.029-07		6d3/2	2.444-02		6g7/2	1.616-04
	6g	1.113-07		7d3/2	1.430-05		7g7/2	1.335-04
	7g	9.732-08		5g	7.565-06			
				6g	7.660-06			
				7g	6.649-06			

TABLE 20 (continued)

i	j	σ^2_{ij}	i	j	σ^2_{ij}	i	j	σ^2_{ij}
z' = 4			z' = 5			z' = 5 (continued)		
5s1/2	6p1/2	5.115-03	5s1/2	5p1/2	1.394-01	5d3/2	5p1/2	3.063-02
	7p1/2	9.575-04		6p1/2	5.962-03		6p1/2	1.735-02
	6p3/2	2.744-04		7p1/2	1.124-03		7p1/2	6.117-04
	7p3/2	2.292-04		5p3/2	1.437-01		5p3/2	3.795-02
6s1/2	6p1/2	6.347-01		6p3/2	4.493-04		6p3/2	9.522-03
	7p1/2	2.380-02		7p3/2	2.778-04		7p3/2	6.964-04
	6p3/2	6.244-01	6s1/2	5p1/2	1.708-02		5f5/2	1.903-02
	7p3/2	1.289-03		6p1/2	6.128-01		6f5/2	4.500-05
5p1/2	6s1/2	1.575-02		7p1/2	2.082-02		7f5/2	2.369-05
	7s1/2	1.573-03		5p3/2	4.968-04	6d3/2	5p1/2	5.652-08
	6d3/2	5.827-06		6p3/2	6.049-01		6p1/2	1.293-01
	7d3/2	2.139-05		7p3/2	6.714-04		7p1/2	2.279-01
6p1/2	7s1/2	1.764-01	5p1/2	5s1/2	1.394-01		5p3/2	4.662-04
	6d3/2	1.310-01		6s1/2	1.708-02		6p3/2	1.870-01
	7d3/2	1.377-03		7s1/2	1.738-03		7p3/2	1.692-01
5p3/2	6s1/2	6.244-01		5d3/2	3.063-02		5f5/2	2.805-02
	7s1/2	2.894-03		6d3/2	5.652-08		6f5/2	9.755-02
	6d3/2	2.995-04		7d3/2	2.902-05		7f5/2	1.104-02
	7d3/2	2.063-04	6p1/2	5s1/2	5.962-03	5f5/2	5d3/2	1.903-02
6p3/2	7s1/2	4.451-01		6s1/2	6.128-01		6d3/2	2.805-02
	6d3/2	1.956-01		7s1/2	1.531-01		7d3/2	1.805-06
	7d3/2	1.665-04		5d3/2	1.735-02		5g7/2	1.583-03
5d3/2	6p1/2	1.646-02		6d3/2	1.293-01		6g7/2	1.279-03
	7p1/2	5.352-04		7d3/2	1.598-03		7g7/2	1.149-03
	6p3/2	8.769-03	5p3/2	5s1/2	1.437-01			
	7p3/2	5.958-04		6s1/2	4.968-02			
	5f5/2	1.189-02		7s1/2	3.182-03			
	6f5/2	6.306-05		5d3/2	3.795-02			
	7f5/2	1.275-05		6d3/2	4.662-04			
6d3/2	6p1/2	1.310-01		7d3/2	2.709-04			
	7p1/2	2.899-01	6p3/2	5s1/2	4.493-04			
	6p3/2	1.956-01		6s1/2	6.049-01			
	7p3/2	2.282-01		7s1/2	3.904-01			
	5f5/2	2.864-02		5d3/2	9.522-03			
	6f5/2	9.668-02		6d3/2	1.870-01			
	7f5/2	1.781-02		7d3/2	1.019-04			
5f5/2	6d3/2	2.864-02						
	7d3/2	2.508-06						
	5g7/2	6.609-04						
	6g7/2	5.473-04						
	7g7/2	4.771-04						

TABLE 20 (continued)

i	j	a_{ij}^2	i	j	a_{ij}^2	i	j	a_{ij}^2
$z' = 6$			$z' = 7$			$z' = 8$		
5s1/2	5p1/2	1.382-01	5s1/2	5p1/2	1.355-01	5s	5p1/2	1.365-01
	6p1/2	5.980-03		6p1/2	5.488-03		6p1/2	6.001-03
	7p1/2	1.231-03		7p1/2	1.250-03		7p1/2	1.450-03
	5p3/2	1.423-01		5p3/2	1.397-01		5p3/2	1.407-01
	6p3/2	4.608-04		6p3/2	3.751-04		6p3/2	4.637-04
	7p3/2	2.944-04		7p3/2	2.657-04		7p3/2	3.322-01
5p1/2	5s1/2	1.382-01	5p1/2	5s1/2	1.355-01	5p1/2	5s1/2	1.365-01
	6s1/2	1.691-02		6s1/2	1.534-02		6s1/2	1.641-02
	7s1/2	1.861-03		7s1/2	1.878-03		7s1/2	2.092-03
	5d3/2	3.038-02		5d3/2	2.973-02		5d3/2	2.998-02
	6d3/2	3.501-08		6d3/2	5.029-07		6d3/2	2.359-07
	7d3/2	3.147-05		7d3/2	2.469-05		7d3/2	3.592-05
5p3/2	5s1/2	1.423-01	5p3/2	5s1/2	1.397-01	5p3/2	5s1/2	1.407-01
	6s1/2	4.908-02		6s1/2	4.538-02		6s1/2	4.768-02
	7s1/2	5.874-02		7s1/2	3.638-03		7s1/2	3.925-03
	5d3/2	3.752-02		5d3/2	3.648-02		5d3/2	3.684-02
	6d3/2	5.254-04		6d3/2	4.847-04		6d3/2	6.028-04
	7d3/2	3.064-04		7d3/2	2.967-04		7d3/2	3.624-04
5d3/2	5p1/2	3.038-02	5d3/2	5p1/2	2.972-02	5d3/2	5p1/2	2.998-02
	6p1/2	1.649-02		6p1/2	1.523-02		6p1/2	1.605-02
	7p1/2	6.921-04		7p1/2	7.725-04		7p1/2	8.066-04
	5p3/2	3.752-02		5p3/2	3.648-02		5p3/2	3.684-02
	6p3/2	9.286-03		6p3/2	8.151-03		6p3/2	8.798-03
	7p3/2	7.655-04		7p3/2	7.842-04		7p3/2	8.453-04
	5f	1.899-02		5f5/2	1.853-02		5f5/2	1.876-02
	6f	3.796-05		6f5/2	3.980-05		6f5/2	2.306-05
	7f	2.954-05		7f5/2	2.330-05		7f5/2	4.329-05
5f5/2	5d3/2	1.897-02	5f5/2	5d3/2	1.853-02	5f5/2	5d3/2	1.876-02
	6d3/2	2.436-02		6d3/2	1.868-02		6d3/2	1.949-02
	7d3/2	5.490-05		7d3/2	2.251-04		7d3/2	1.760-04
	5g7/2	2.601-03		5g7/2	3.367-03	5f5/2	5g7/2	5.662-03
	6g7/2	2.894-03		6g7/2	2.720-03		6g7/2	3.886-03
	7g7/2	1.944-03		7g7/2	2.359-03		7g7/2	2.265-03

TABLE 20 (continued)

i	j	σ^2_{ij}	i	j	σ^2_{ij}	i	j	σ^2_{ij}
z' = 9			z' = 10			z' = 11		
5s1/2	5p1/2	1.351-01	5s1/2	5p1/2	1.367-01	5s1/2	5p1/2	1.370-01
	6p1/2	5.614-03		6p1/2	4.894-03		6p1/2	5.185-03
	7p1/2	1.495-03		7p1/2	1.740-03		7p1/2	1.871-03
	5p3/2	1.392-01		5p3/2	1.409-01		5p3/2	1.411-01
	6p3/2	3.772-04		6p3/2	2.130-04		6p3/2	2.594-04
	7p3/2	3.238-04		7p3/2	4.191-04		7p3/2	4.645-04
5p1/2	5s1/2	1.351-01	5p1/2	5s1/2	1.367-01	5p1/2	5s1/2	1.370-01
	6s1/2	1.540-02		6s1/2	1.453-02		6s1/2	1.513-02
	7s1/2	2.135-03		7s1/2	2.362-03		7s1/2	2.503-03
	5d3/2	2.963-02		5d3/2	3.000-02		5d3/2	3.009-02
	6d3/2	1.492-07		6d3/2	1.164-05		6d3/2	6.688-06
	7d3/2	3.372-05		7d3/2	5.029-05		7d3/2	6.102-05
5p3/2	5s1/2	1.392-01	5p3/2	5s1/2	1.409-01	5p3/2	5s1/2	1.411-01
	6s1/2	4.556-02		6s1/2	4.391-02		6s1/2	4.494-02
	7s1/2	4.087-03		7s1/2	4.320-03		7s1/2	4.451-03
	5d3/2	3.632-02		5d3/2	3.682-02		5d3/2	3.686-02
	6d3/2	5.700-04		6d3/2	4.182-04		6d3/2	4.927-04
	7d3/2	3.682-04		7d3/2	4.107-04		7d3/2	4.810-04
5d3/2	5p1/2	2.963-02	5d3/2	5p1/2	3.000-02	5d3/2	5p1/2	3.009-02
	6p1/2	1.513-02		6p1/2	1.489-01		6p1/2	1.516-02
	7p1/2	8.515-04		7p1/2	8.586-04		7p1/2	8.578-04
	5p3/2	3.632-02		5p3/2	3.682-02		5p3/2	3.686-02
	6p3/2	8.178-03		6p3/2	8.910-02		6p3/2	8.177-03
	7p3/2	8.537-04		7p3/2	8.972-04		7p3/2	9.008-04
	5f5/2	1.852-02		5f5/2	1.885-02		5f5/2	1.891-02
	6f5/2	2.501-05		6f5/2	8.470-05		6f5/2	5.355-05
	7f5/2	4.531-05		7f5/2	7.714-05		7f5/2	9.953-05
5f5/2	5d3/2	1.852-02	5f5/2	5d3/2	1.885-02	5f5/2	5d3/2	1.891-02
	6d3/2	1.671-02		6d3/2	1.626-02		6d3/2	1.570-02
	7d3/2	2.444-04		7d3/2	1.924-04		7d3/2	1.861-04
	5g7/2	7.316-03		5g7/2	9.753-03		5g7/2	1.159-02
	6g7/2	4.092-03		6g7/2	3.963-03		6g7/2	3.483-03
	7g7/2	1.503-03		7g7/2	7.674-04		7g7/2	3.260-04

TABLE 20 (continued)

i	j	σ^2_{ij}
	z' = 12	
5s1/2	5p1/2	1. 372-01
	6p1/2	5. 437-03
	7p1/2	1. 982-03
	5p3/2	1. 411-01
	6p3/2	3. 016-04
	7p3/2	5. 037-04
5p1/2	5s1/2	1. 372-01
	6s1/2	1. 572-02
	7s1/2	2. 620-03
	5d3/2	3. 016-02
	6d3/2	2. 931-06
	7d3/2	7. 228-05
5p3/2	5s1/2	1. 411-01
	6s1/2	4. 598-02
	7s1/2	4. 571-03
	5d3/2	3. 689-02
	6d3/2	5. 694-04
	7d3/2	5. 188-04
5d3/2	5p1/2	3. 016-02
	6p1/2	1. 532-02
	7p1/2	8. 557-04
	5p3/2	3. 689-02
	6p3/2	8. 335-03
	7p3/2	8. 994-04
	5f5/2	1. 893-02
	6f5/2	2. 883-05
	7f5/2	1. 216-04
5f5/2	5d3/2	1. 893-02
	6d3/2	1. 486-02
	7d3/2	1. 882-04
	5g7/2	.. 293-02
	6g7/2	2. 768-03
	7g7/2	1. 061-04

BATES-DAMGAARD TABLES[27]

$$\sigma^2(n^*(\ell - 1),\ n^*(\ell),\ \ell) = \frac{F^2 I^2}{z'^2} \quad , \tag{B-1}$$

where

$$F^2 = \left(\frac{3n^*}{2}\right)^2 \left(\frac{n^{*2} - \ell^2}{4\ell^2 - 1}\right) . \tag{B-2}$$

We obtain I from

$$I = I_\infty + \frac{J}{n^* - \ell} + \frac{K}{(n^* - \ell)^2} \quad , \tag{B-3}$$

where I_∞, J, K are obtained from tables by means of

A) $\ell = 1$

$$\begin{pmatrix} I_\infty \\ J \\ K \end{pmatrix} = \frac{1}{8} \begin{pmatrix} 25 & -18 & 1 \\ -100 & 108 & -8 \\ 75 & -90 & 15 \end{pmatrix} \begin{pmatrix} I_6 \\ I_4 \\ I_2 \end{pmatrix} \tag{B-4}$$

B) $\ell = 2$

$$\begin{pmatrix} I_\infty \\ J \\ K \end{pmatrix} = \frac{1}{3} \begin{pmatrix} 8 & -6 & 1 \\ -24 & 30 & -6 \\ 16 & -24 & 8 \end{pmatrix} \begin{pmatrix} I_6 \\ I_4 \\ I_3 \end{pmatrix} \tag{B-5}$$

C) $\ell = 3$

$$\begin{pmatrix} I_\infty \\ J \\ K \end{pmatrix} = \frac{1}{2} \begin{pmatrix} 9 & -8 & 1 \\ -27 & 32 & -5 \\ 18 & -24 & 6 \end{pmatrix} \begin{pmatrix} I_6 \\ I_5 \\ I_4 \end{pmatrix} \tag{B-6}$$

Here the subscripts on I refer to the $n^*(\ell)$ column headings in Table 21 and

$$\Delta n = n^*(\ell - 1) - n^*(\ell) . \tag{B-7}$$

TABLE 21

THE FUNCTION $I(n'(\ell'-1), n'(\ell'), \ell')$ FOR COULOMB APPROXIMATION BOUND-BOUND TRANSITIONS[a]

	$n'(\ell')$								
	$\ell' = 1$			$\ell' = 2$			$\ell' = 3$		
$n(\ell-1) - n(\ell)$	2	4	6	3	4	6	4	5	6
-1.5	0.026	-0.046	-0.063	0.131	+0.006	-0.048	0.244	+0.047	-0.007
-1.4	0.048	-0.015	-0.031	0.182	0.055	-0.004	0.313	0.113	+0.051
-1.3	0.080	+0.028	+0.014	0.242	0.117	+0.053	0.389	0.190	0.123
-1.2	0.123	0.084	0.072	0.311	0.190	0.123	0.471	0.276	0.206
-1.1	0.180	0.154	0.145	0.388	0.273	0.205	0.557	0.370	0.298
-1.0	0.248	0.235	0.229	0.472	0.364	0.208	0.644	0.469	0.397
-0.9	0.329	0.327	0.323	0.559	0.461	0.398	0.731	0.569	0.500
-0.8	0.418	0.425	0.425	0.648	0.560	0.501	0.813	0.668	0.603
-0.7	0.514	0.527	0.528	0.734	0.657	0.604	0.888	0.761	0.703
-0.6	0.612	0.629	0.632	0.814	0.750	0.703	0.952	0.845	0.794
-0.5	0.708	0.725	0.730	0.885	0.833	0.794	1.004	0.916	0.874
-0.4	0.797	0.813	0.818	0.944	0.903	0.872	1.040	0.972	0.938
-0.3	0.875	0.888	0.892	0.987	0.957	0.935	1.058	1.010	0.985
-0.2	0.937	0.946	0.949	1.011	0.993	0.978	1.058	1.028	1.012
-0.1	0.980	0.984	0.985	1.016	1.007	1.000	1.038	1.024	1.017
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
+0.1	0.996	0.992	0.992	0.963	0.971	0.977	0.944	0.955	0.962
0.2	0.967	0.961	0.960	0.907	0.921	0.933	0.872	0.892	0.904
0.3	0.915	0.908	0.906	0.834	0.852	0.868	0.786	0.813	0.829
0.4	0.842	0.835	0.831	0.746	0.767	0.786	0.691	0.722	0.740
0.5	0.749	0.745	0.743	0.646	0.670	0.691	0.588	0.621	0.641
0.6	0.643	0.642	0.642	0.540	0.564	0.587	0.483	0.515	0.535
0.7	0.528	0.531	0.532	0.431	0.455	0.479	0.379	0.409	0.428
0.8	0.409	0.417	0.420	0.324	0.346	0.369	0.279	0.305	0.323
0.9	0.292	0.304	0.309	0.222	0.242	0.264	0.185	0.209	0.224
1.0	0.181	0.198	0.204	0.129	0.147	0.166	0.105	0.122	0.134
1.1	+0.081	0.102	0.108	+0.049	+0.063	0.080	+0.035	+0.047	+0.057
1.2	-0.004	+0.019	+0.025	-0.017	-0.006	+0.008	-0.020	-0.013	-0.007
1.3	-0.071	-0.047	-0.040	-0.067	-0.060	-0.050	-0.061	-0.059	-0.055
1.4	-0.120	-0.096	-0.089	-0.101	-0.097	-0.091	-0.088	-0.089	-0.088
1.5	-0.149	-0.128	-0.122	-0.120	-0.119	-0.116	-0.101	-0.105	-0.107

[a] This table is obtained from Ref. 27.

KRAMERS' APPROXIMATION FOR BOUND-BOUND TRANSITIONS

We express the Kramers approximation for r_{ij} in the form

$$r_{ij} = \frac{32}{\pi\sqrt{3}} \frac{z'^6}{n^2} \left(\frac{Ry}{\hbar\omega}\right)^4 \frac{1}{(n^* n^{*\prime})^3} \quad . \tag{B-8}$$

BOUND-BOUND STF TABLES

STF values of σ_{ij}^2 are given in Table 20.

BURGESS-SEATON TABLES[28]

For bound-free transitions,

$$r = \frac{n^{*4}}{z'^4} g^2 \quad . \tag{B-9}$$

For bound-bound transitions,

$$r = \frac{2z'^2}{\pi n^{*\prime 3}} \frac{n^{*4}}{z'^4} g^2 \quad . \tag{B-10}$$

In either case,

$$g^2 = G^2 E^{-2\gamma} \cos^2 \phi \quad . \tag{B-11}$$

The functions $G = G_{\ell\ell'}$ and $\gamma = \gamma_{\ell\ell'}$ follow from Table 22:

$$E = \frac{n^{*2}}{z'^2} \left(\frac{\hbar\omega}{Ry}\right) \quad , \tag{B-12}$$

$$\phi = \pi[\mu' - \mu + \psi] \quad , \tag{B-13}$$

$$\psi = \psi_{\ell\ell'} = \chi_{\ell\ell'} + \frac{E-1}{n^* + E - 1} \alpha_{\ell\ell'} + \frac{E-1}{E} \beta_{\ell\ell'} \quad . \tag{B-14}$$

The functions χ, α, β are given in Table 22.

TABLE 22

THE FUNCTIONS FOR COULOMB APPROXIMATION BOUND-FREE TRANSITIONS[a]

	n* Range	a	b	c	a	b	c	a	b	c
s-p		G_{01}			γ_{01}			χ_{01}		
$\alpha = 0.250$, $\beta = 0$	0.0-1.0⁻	1.287	1.855	-0.432	1.268	0.560	-0.126	-0.179	0.265	-0.043
	1.0-1.4⁻	1.086	2.111	-0.458	1.667	0.255	+0.290	-0.0545	-0.0159	+0.113
	1.4-2.0⁻	1.655	0.629	0.500	1.539	0.0944	0.0299	-0.174	0.344	-0.157
	2.0-6.0⁻	1.164	2.570	-1.416	1.594	0	0	-0.147	0.2515	-0.078
	6.0-∞⁻	0.996	4.602	-7.560	1.598	0	0	-0.147	0.2515	-0.078
p-s		$\frac{G_{10}}{[n(p)-1]^{\frac{1}{2}}}$			γ_{10}			χ_{10}		
$\alpha = 0$, $\beta = 0$	1.0-2.0	0.6617	0.131	1.087	1.5017	0.830	0.999	-0.236	-0.144	0.049
		G_{10}								
	2.0-3.0⁻	1.353	-0.708	0	5/3	0	0	$(-0.273 - 0.022(3-n^*))$		
	3.0-6.0⁻	1.185	+0.084	-0.864	5/3	0	0	-0.216	-0.171	0
	6.0-∞⁻	1.081	1.356	-4.752	5/3	0	0	-0.216	-0.171	0
p-d		$\frac{G_{12}}{[n(p)-1]^{\frac{1}{2}}}$			γ_{12}			χ_{12}		
$\alpha = 0.320$, $\beta = \beta_{12}$	1.0-2.0	-8.392	30.513	-16.431	2.436	-3.351	+3.255	-0.4585	1.3815	-0.273
		G_{12}								
	2.0-3.0⁻	3.375	-7.644	12.816	1.576	0	0	-0.409	2.046	-1.800
$\alpha = 0.320$, $\beta = 0.0535$	3.0-6.0⁻	1.206	3.342	-0.504	1.596	0	0	-0.120	0.600	0
	6.0-∞	1.000	5.754	-7.560	1.596	0	0	-0.120	0.600	0
d-p		G_{21}			γ_{21}			χ_{21}		
$\alpha = -0.010$, $\beta = -0.019$	0.0-6.0⁻	1.213	-1.53	-0.200	1.707	0	0	-0.247	-0.272	0
	6.0-∞	1.127	-0.438	-3.672	1.707	0	0	-0.247	-0.272	0
d-f		G_{23}			γ_{23}			χ_{23}		
$\alpha = 0.321$, $\beta = 0.106$	0.0-6.0⁻	1.307	3.104	5.280	1.565	0	0	-0.117	1.170	0
	6.0-∞⁻	1.040	6.486	-5.400	1.565	0	0	-0.117	1.170	0
f-d		G_{32}			γ_{32}			χ_{32}		
$\alpha = -0.390$, $\beta = 0.050$	0.0-∞⁻	1.691	-8.622	16.200	1.921	0	0	-0.362	0.599	-2.432

NOTE $G, \gamma, \chi = a + b/n^* + c/n^{*2}$

n^*	β_{12}
1.0	0.079
1.2	0.069
1.4	0.054
1.6	0.038
1.8	0.029
2.0	0.035
2.2	0.053
2.4	0.068
2.6	0.068
2.8	0.060
3.0	0.050

[a] This table is based on Tables 5-2 through 5-7 in Ref. 29.

$$\mu' = \mu'_a + \left(\frac{d\mu'}{dE}\right)_a (E' + E_a) \qquad \text{(B-15)}$$

E' = KE = kinetic energy of electron in the bound-free case

$$= -\frac{z'^2 Ry}{n^{*'2}} \text{ in the bound-bound case.} \qquad \text{(B-16)}$$

We calculate μ'_a and $(d\mu'/dE)_a$ from Table 23 using the quantum defects at high principal quantum numbers.

KRAMERS' APPROXIMATION FOR BOUND-FREE TRANSITIONS

For bound-free transitions, we express Kramers' formula in the form

$$r = \frac{16}{\sqrt{3}} \frac{z'^4}{n^2} \frac{1}{n^{*3}} \left(\frac{Ry}{\hbar\omega}\right)^4 . \qquad \text{(B-17)}$$

BOUND-FREE STF TABLES

For bound-free transitions,

$$r = (4\ell_>^2 - 1) \left(\frac{Ry}{KE}\right)^{\frac{1}{2}} \sigma^2(KE) . \qquad \text{(B-18)}$$

Table 24 gives values of σ and the energies at which they are evaluated. If KE is in the range $KE_j < KE \leq KE_{j+1}$, and $\sigma(KE)$ does not change sign, we linearly interpolate

$$\sigma'^2(KE) = \left(\frac{Ry}{KE}\right)^{\frac{1}{2}} \sigma^2(KE) \qquad \text{(B-19)}$$

on a scale that is logarithmic in both σ'^2 and KE. If $\sigma(KE)$ does change sign in this range, we assume that σ is a linear function of KE.

TABLE 23

ASYMPTOTIC QUANTUM DEFECTS

z'	E_{as} (Ry)	μ_{as}	$\left(\frac{d\mu}{dE}\right)_{as}$ [(Ry)$^{-1}$]	z'	E_{as} (Ry)	μ_{as}	$\left(\frac{d\mu}{dE}\right)_{as}$ [(Ry)$^{-1}$]
		$s_{1/2}$				$p_{1/2}$	
1	7.9109-02	5.44	-1.3553-01	1	6.1968-02	4.98	-4.0245-01
2	1.5048-01	4.84	-9.9951-02	2	1.3139-01	4.46	-2.1100-01
3	4.3711-01	4.46	-5.6456-02	3	3.8209-01	4.14	-7.6642-02
4	6.8375-01	4.16	-3.6231-02	4	6.0949-01	3.87	-5.0687-02
5	6.7382-01	3.91	-2.4874-02	5	6.1848-01	3.64	-3.5247-02
6	9.0675-01	3.70	-1.9320-02	6	8.3874-01	3.45	-2.6714-02
7	1.1651+00	3.51	-1.5177-02	7	1.0834+00	3.28	-2.0643-02
8	1.4476+00	3.35	-1.2091-02	8	1.3540+00	3.12	-1.7009-02
9	1.7539+00	3.20	-1.0104-02	9	1.6467+00	2.98	-1.3847-02
10	2.0821+00	3.07	-8.4679-03	10	1.9618+00	2.86	-1.1461-02
11	2.4310+00	2.94	-5.4889-03	11	2.2985+00	2.74	-8.9921-03
12	2.8017+00	2.83	-4.4566-03	12	2.6561+00	2.63	-7.4882-03
		$p_{3/2}$				d	
1	2.7713-01	4.78	-1.1759-01	1	3.8162-02	3.88	-3.7608-01
2	6.4795-01	4.29	-1.2975-01	2	9.7223-02	3.58	-1.9184-01
3	1.1126+00	3.99	-8.2499-02	3	2.8140-01	3.34	-1.1127-01
4	1.6384+00	3.73	-4.2033-02	4	4.6521-01	3.13	-7.4741-02
5	5.9238-01	3.50	-3.5617-02	5	5.0267-01	2.94	-4.8402-02
6	8.0434-01	3.31	-2.7022-02	6	6.9236-01	2.79	-3.6132-02
7	1.0410+00	3.14	-2.1309-02	7	9.0674-01	2.65	-2.7308-02
8	1.3010+00	2.98	-1.6691-02	8	1.1442+00	2.52	-2.1592-02
9	1.5835+00	2.84	-1.3879-02	9	1.4039+00	2.40	-1.7942-02
10	1.8876+00	2.72	-1.1445-02	10	1.6852+00	2.29	-1.4660-02
11	2.2130+00	2.60	-9.0365-03	11	1.9876+00	2.19	-1.2003-02
12	2.5588+00	2.49	-7.2591-03	12	2.3103+00	2.10	-1.0341-02
		f					
1	2.0467-02	2.00	1.2169-01				
2	6.3532-02	2.00	1.8918-01				
3	1.8790	2.00	7.4583-02				
4	3.2995-01	2.00	5.8416-03				
5	5.0524-01	1.965	-9.3181-03				
6	5.4649-01	1.880	-1.7579-02				
7	7.2924-01	1.800	-1.6537-02				
8	9.3443-01	1.720	-1.5225-02				
9	1.1614+00	1.650	-1.3263-02				
10	1.4095+00	1.570	-1.1745-02				
11	1.6784+00	1.500	-9.9834-03				
12	1.9676+00	1.440	-8.5944-03				

TABLE 24

STF BOUND-FREE σ_{ij}

KE (Ry)	$s_{1/2}\to kp_{1/2}$	$s_{1/2}\to kp_{3/2}$	$p_{1/2}\to kp_{1/2}$	$p_{1/2}\to kd$	$p_{3/2}\to ks_{1/2}$	$p_{3/2}\to kd$	$d\to kp_{1/2}$	$d\to kp_{3/2}$	$d\to kf$	$f\to kd$	$f\to kg$
$z'=1 \quad n=5$											
1.0-03	6.2666-03	6.9325-04	8.9340-03	1.4451-02	1.9894-03	1.9882-03	9.3612-03	8.6381-03	2.2035-03	3.0263-02	1.7049-03
3.0-03	8.2451-03	9.1273-04	1.1755-02	2.6157-02	1.9013-02	2.6158-03	1.2313-02	1.1365-02	4.9331-03	3.9693-02	2.2995-03
7.0-03	1.0838-02	1.1289-03	1.4521-02	3.2269-03	2.3485-02	2.2306-03	1.5201-02	1.4039-02	3.7062-03	2.8728-02	2.9795-03
1.0-02	1.1129-02	1.2350-03	1.5870-02	3.5231-03	2.5665-02	3.5302-03	1.6606-02	1.5342-02	4.1178-03	5.3006-02	3.3696-03
3.0-02	1.4604-02	1.6296-03	2.0436-02	4.5951-03	3.3679-02	4.6310-03	2.1738-02	2.0114-02	5.9821-03	6.7506-02	5.4082-03
7.0-02	1.7954-02	2.0293-03	2.5630-02	5.5835-03	4.1392-02	5.6923-03	2.6597-02	2.4718-02	8.6993-03	7.8396-02	9.0257-03
1.0-01	1.9560-02	2.2309-03	2.7267-02	6.0326-03	5.5071-02	6.2030-03	2.8917-02	2.6908-02	1.0511-02	8.2030-02	1.1728-02
3.0-01	2.5310-02	3.0408-03	3.6006-02	7.4369-03	5.7899-02	8.0899-03	3.6495-02	3.4414-02	2.0903-02	8.4429-02	3.0059-02
7.0-01	3.0703-02	4.0018-03	4.3168-02	8.3036-03	6.8769-02	1.0068-02	4.2323-02	4.0208-02	3.4337-02	7.3517-02	6.4895-02
1.0+00	3.3207-02	4.5598-03	4.6220-02	8.4711-03	7.3176-02	1.1110-02	4.5165-02	4.2181-02	3.8805-02	6.6008-02	8.8154-02
3.0+00	4.0746-02	7.2529-03	5.3483-02	1.2300-03	8.1691-02	1.5448-02	4.2937-02	3.2658-02	3.9661-02	3.6916-01
7.0+00	4.3670-02	1.0601-02	5.2800-02	3.1544-03	7.6300-02	1.9277-02	3.7113-02	3.5040-02	1.0420-02	2.2287-02	1.0940-01
1.0+01	4.3525-02	1.2140-02	4.9700-02	6.4581-04	6.9640-02	2.0273-02	3.1774-02	2.9863-02	1.2198-03	1.6565-02	4.6740-02
$z'=1 \quad n=6$											
1.0-03	1.6957-02	1.8337-02	6.7063-02	4.6827-02	1.0996-01	4.4901-02	9.0832-02	1.2911-01	1.4957-01		
3.0-03	2.2308-02	2.4096-02	8.8972-02	6.1618-02	1.4453-01	5.9024-02	1.1883-01	1.6887-01	1.9759-01		
7.0-03	2.7553-02	2.9692-02	1.0976-01	7.6126-02	1.7816-02	7.2776-02	1.4515-01	2.0615-01	2.4597-01		
1.0-02	3.0107-02	3.2388-02	1.1984-01	8.3198-02	1.9440-01	7.9417-02	1.5731-01	2.2332-01	2.7026-01		
3.0-02	3.9492-02	4.1993-02	1.5631-01	1.0915-01	2.5252-01	1.0316-01	1.9572-01	2.7704-01	3.6553-01		
7.0-02	4.8516-02	5.0400-02	1.8976-01	1.3355-01	3.0412-01	1.2375-01	2.1822-01	3.0704-01	4.0594-01		
1.0-01	5.2828-02	5.3929-02	2.0471-01	1.4454-01	3.2619-01	1.3198-01	2.2237-01	3.1148-01	5.1435-01		
3.0-01	6.6170-02	6.1977-02	2.4720-01	1.7300-01	3.8032-01	1.4366-01	2.0276-01	2.7591-01	6.3469-01		
7.0-01	8.1893-02	5.9558-02	2.6072-01	1.7005-01	3.7859-01	1.1789-01	1.5632-01	2.0329-01	5.5065-01		
1.0+00	8.7541-02	5.4242-02	2.5593-01	1.5687-01	3.5918-01	9.5258-02	1.3283-01	1.6843-01	4.4078-01		
3.0+00	9.5521-02	2.0502-02	1.9216-01	8.1077-02	2.3699-01	1.5276-02	6.5791-02	7.5756-02	1.1905-01		
7.0+00	8.0561-02	-6.1169-03	1.1553-01	2.6296-02	1.3048-01	-1.5085-02	3.1509-02	3.3398-02	2.2744-02		
1.0+01	6.9067-02	-1.2080-02	8.6354-02	1.2267-02	9.5152-02	-1.8028-02	2.2179-02	2.2727-02	7.5594-03		
$z'=2 \quad n=5$											
1.0-03	5.9169-03	8.0539-04	8.3440-03	1.5309-03	1.3302-02	2.0297-03	8.2108-03	7.7325-03	5.1778-03	1.6282-02	6.4493-03
3.0-03	7.8404-03	1.0603-03	1.0977-02	2.0137-03	1.7503-02	2.6713-03	1.0902-02	1.0166-02	6.8245-03	2.1394-02	8.5301-03
7.0-03	9.6897-03	1.3112-03	1.3564-02	2.4863-03	2.1624-02	3.3015-03	1.3344-02	1.2558-02	8.4597-03	2.6358-02	1.0649-02
1.0-02	1.0592-02	1.4328-03	1.4825-02	2.7160-03	2.3633-02	3.6096-03	1.4582-02	1.3724-02	9.2691-03	2.8747-02	1.1726-02
3.0-02	1.3929-02	1.6911-03	1.9480-02	3.5563-03	3.1040-02	4.7508-03	1.9134-02	1.8017-02	1.2371-02	3.7248-02	1.6171-02
7.0-02	1.7189-02	2.3505-03	2.4000-02	4.3510-03	3.8207-02	5.8731-03	2.3511-02	2.2155-02	1.5674-02	4.4656-02	2.1756-02
1.0-01	1.8770-02	2.5804-03	2.6174-02	4.7211-03	4.1645-02	6.4224-03	2.5592-02	2.4129-02	1.7417-02	4.7752-02	2.5165-02
3.0-01	2.4510-02	3.4858-03	3.3926-02	5.9211-03	5.3754-02	8.4789-03	3.2729-02	3.0943-02	2.4540-02	5.4872-02	4.3750-02
7.0-01	2.9840-02	4.5078-03	4.0770-02	6.6439-03	6.4089-02	1.0583-02	3.8274-02	3.6274-02	3.0923-02	5.4118-02	7.4111-02
1.0+00	3.2269-02	5.0769-03	4.3704-02	6.8401-02	6.8308-02	1.1663-02	4.0218-02	3.8130-02	3.2495-02	5.1366-02	9.3591-02
3.0+00	3.9584-02	7.6999-03	5.0931-02	5.7329-03	7.6940-02	1.5859-02	4.1680-02	3.9440-02	2.5108-02	3.5588-02	1.6260-01
7.0+00	4.2714-02	1.0834-02	5.0673-02	2.0723-03	7.2677-02	1.9314-02	3.5063-02	3.2953-02	6.9107-03	2.1327-02	9.4632-02
1.0+01	4.2470-02	1.2251-02	4.7934-02	1.8472-04	6.6773-02	2.0170-02	3.0350-02	2.8376-02	8.2867-04	1.6127-02	3.8417-02

TABLE 24 (continued)

KE(Ry)	$s_{1/2}\rightarrow kp_{1/2}$	$s_{1/2}\rightarrow kp_{3/2}$	$p_{1/2}\rightarrow kp_{1/2}$	$p_{1/2}\rightarrow kd$	$p_{3/2}\rightarrow ks_{1/2}$	$p_{3/2}\rightarrow kd$	$d\rightarrow kp_{1/2}$	$d\rightarrow kp_{3/2}$	$d\rightarrow kf$	$f\rightarrow kd$	$f\rightarrow kg$
					$z' = 2$ $n = 6$						
1.0-03	1.6259-02	1.3349-02	5.5593-02	3.7885-02	8.3393-02	2.9081-02	4.2503-02	5.5572-02	1.3716-01		
3.0-03	2.1394-02	1.7546-02	7.3102-02	4.9798-02	1.0963-01	3.8190-02	5.5799-02	7.2941-02	1.8022-01		
7.0-03	2.8435-02	2.1633-02	9.0204-02	6.1402-02	1.3519-01	4.7004-02	6.8629-02	8.9679-02	2.2200-01		
1.0-02	2.8893-02	2.3606-02	9.8495-02	6.7004-02	1.4755-01	5.1223-02	7.4754-02	9.7653-02	2.4209-01		
3.0-02	3.7974-02	3.0684-02	1.2857-01	8.7131-02	1.9206-01	6.6009-02	9.6048-02	1.2523-01	3.1324-01		
7.0-02	4.8801-02	3.6997-02	1.5637-01	1.0515-01	2.3227-01	7.8233-02	1.1334-01	1.4722-01	3.7367-01		
1.0-01	5.1056-02	3.9703-02	1.6892-01	1.1292-01	2.4988-01	8.2868-02	1.1984-01	1.5523-01	3.9747-01		
3.0-01	6.6191-02	4.6197-02	2.0590-01	1.3222-01	2.9689-01	8.8786-02	1.2934-01	1.6464-01	4.3017-01		
7.0-01	7.9200-02	4.4755-02	2.2114-01	1.3096-01	3.0562-01	7.3624-02	1.1720-01	1.4483-01	3.5664-01		
1.0+00	8.4349-02	4.0803-02	2.1962-01	1.2249-01	2.9573-01	6.0031-02	1.0634-01	1.2902-01	2.9378-01		
3.0+00	9.1255-02	1.4491-02	1.7295-01	6.7671-02	2.0987-01	6.9946-03	6.1921-02	6.9704-02	9.5258-02		
7.0+00	7.7402-02	-7.4549-03	1.0812-01	2.3077-02	1.2138-01	-1.5754-02	3.1962-02	3.3481-02	1.9553-02		
1.0+01	6.6711-02	-1.2522-02	8.2088-02	1.0830-02	8.9986-02	-1.7936-02	2.2849-02	2.3268-02	6.0916-03		
					$z' = 3$ $n = 5$						
1.0-02	1.0482-02	1.4259-03	1.4662-02	2.6737-03	2.3061-02	3.4768-03	1.3917-02	1.3274-02	1.2740-02	1.9082-02	3.0376-02
3.0-02	1.3787-02	1.8816-03	1.9270-02	3.5029-03	3.0297-02	4.5785-03	1.8266-02	1.7423-02	1.6731-02	2.4836-02	4.0464-02
7.0-02	1.7018-02	2.3378-03	2.3751-02	4.2902-03	3.7311-02	5.6660-03	2.2453-02	2.1417-02	2.0581-02	3.0034-02	5.1149-02
1.0-01	1.8587-02	2.5658-03	2.5914-02	4.6588-03	4.0684-02	6.2004-03	2.4449-02	2.3321-02	2.2415-02	3.2313-02	5.6801-02
3.0-01	2.4390-02	3.4593-03	3.3642-02	5.8648-03	5.2607-02	8.2142-03	3.1314-02	2.9862-02	2.8578-02	3.8469-02	8.1201-02
7.0-01	2.9615-02	4.4690-03	4.0486-02	6.6467-03	6.2823-02	1.0288-02	3.6692-02	3.4999-02	3.2501-02	3.9987-02	1.1083-01
1.0+00	3.2030-02	5.0315-03	4.3406-02	6.8150-03	6.6980-02	1.1353-02	3.8581-02	3.6798-02	3.2953-02	3.9076-02	1.2640-01
3.0+00	3.9226-02	7.6190-03	5.0563-02	5.7640-03	7.5480-02	1.5515-02	4.0071-02	3.8104-02	2.4090-02	2.9773-02	1.6049-01
7.0+00	4.2305-02	1.0713-02	5.0279-02	2.1471-03	7.1362-02	1.8922-02	3.3832-02	3.1944-02	6.5537-03	1.8863-02	7.8793-02
1.0+01	4.2048-02	1.2111-02	4.7543-02	9.4543-05	6.5593-02	1.9767-02	2.9348-02	2.7547-02	-8.7084-04	1.4509-02	3.1137-02
3.0+01	3.2986-02	1.3917-02	3.0255-02	-6.0558-03	3.7951-02	1.7060-02	1.4103-02	1.2770-02	-1.1429-02	4.9531-03	-1.3181-02
7.0+01	2.0450-02	1.0819-02	1.5475-02	-6.2738-03	1.8505-02	1.0798-02	6.0787-03	5.2190-03	-8.4434-03	1.6833-03	-6.8540-03
1.0+02	1.5493-02	8.8609-03	1.0835-02	-5.4506-03	1.2825-02	8.2174-03	4.0506-03	3.3789-03	-6.4457-03	9.9532-04	-4.3209-03
					$z' = 3$ $n = 6$						
1.0-02	2.7727-02	1.6093-02	8.0370-02	4.8922-02	1.1209-01	2.9009-02	4.5696-02	5.7743-02	1.4447-01		
3.0-02	3.6429-02	2.0924-02	1.0503-01	6.3671-02	1.4619-01	3.7419-02	5.9249-02	7.4750-02	1.8621-01		
7.0-02	4.4874-02	2.5247-02	1.2802-01	7.6968-02	1.7749-01	4.4432-02	7.1122-02	8.9460-02	2.2081-01		
1.0-01	4.8936-02	2.7104-02	1.3853-01	8.2768-02	1.9150-01	4.7142-02	7.6112-02	9.5513-02	2.3409-01		
3.0-01	6.3271-02	3.1615-02	1.7056-01	9.7857-02	2.3153-01	5.0906-02	8.7715-02	1.0855-01	2.5351-01		
7.0-01	7.5315-02	3.0654-02	1.8618-01	9.8859-02	2.4504-01	4.2521-02	8.6502-02	1.0449-01	2.1866-01		
1.0+00	7.9952-02	2.7863-02	1.8674-01	9.3794-02	2.4106-01	3.4524-02	8.1841-02	9.7355-02	1.8762-01		
3.0+00	8.5967-02	8.4455-03	1.5363-01	5.5296-02	1.8273-01	3.0468-04	5.4209-02	6.0337-02	7.1973-02		
7.0+00	7.3612-02	-8.7648-03	9.9921-02	1.9851-02	1.1113-01	-1.6061-02	3.0132-02	3.1426-02	1.5958-02		
1.0+01	6.3841-02	-1.2868-02	7.7042-02	9.3902-03	8.3785-02	-1.7537-02	2.2116-02	2.2416-02	4.6915-03		
3.0+01	3.1091-02	-1.2630-02	2.7132-02	3.6699-03	2.8734-02	-1.1661-02	6.9991-03	6.4982-03	4.8552-03		
7.0+01	1.4381-02	-7.5782-03	1.0188-02	3.7191-03	1.0716-02	-5.9728-03	2.5148-03	2.1756-03	3.2396-03		
1.0+02	9.9436-03	-5.6982-03	6.4648-03	3.0412-03	6.9294-03	-4.3128-03	1.5690-03	1.3240-03	2.3875-03		

TABLE 24 (continued)

KE(Ry)	$s_{1/2}\rightarrow kp_{1/2}$	$s_{1/2}\rightarrow kp_{3/2}$	$p_{1/2}\rightarrow kp_{1/2}$	$p_{1/2}\rightarrow kd$	$p_{3/2}\rightarrow ks_{1/2}$	$p_{3/2}\rightarrow kd$	$d\rightarrow kp_{1/2}$	$d\rightarrow kp_{3/2}$	$d\rightarrow kf$	$f\rightarrow kd$	$f\rightarrow kg$
					$z' = 4 \quad n = 5$						
1.0-02	1.0303-02	1.6451-03	1.3913-02	2.2621-03	2.1622-02	3.5957-03	1.2563-02	1.1990-02	1.0963-02	1.3560-02	3.8495-02
3.0-02	1.3551-02	2.1693-03	1.8287-02	2.9643-03	2.8409-02	4.7351-03	1.6492-02	1.5739-02	1.4356-02	1.7709-02	5.0866-02
7.0-02	1.6726-02	2.6913-03	2.2543-02	3.6321-03	3.4996-02	5.8588-03	2.0279-02	1.9352-02	1.7566-02	2.1551-02	6.3338-02
1.0-01	1.8266-02	2.9505-03	2.4599-02	3.9451-03	3.8165-02	6.4106-03	2.2083-02	2.1074-02	1.9060-02	2.3295-02	6.9608-02
3.0-01	2.3879-02	3.9546-03	3.1964-02	4.9730-03	4.9412-02	8.4830-03	2.8338-02	2.7038-02	2.3816-02	2.8510-02	9.4220-02
7.0-01	2.9101-02	5.0491-03	3.8520-02	5.6384-03	5.9124-02	1.0589-02	3.3320-02	3.1765-02	2.6419-02	3.0903-02	1.2004-01
1.0+00	3.1477-02	5.6440-03	4.1333-02	5.7761-03	6.3116-02	1.1652-02	3.5123-02	3.3474-02	2.6510-02	3.0917-02	1.3212-01
3.0+00	3.8590-02	8.2738-03	4.8314-02	4.7965-03	7.1543-02	1.5675-02	3.6992-02	3.5150-02	1.8792-02	2.5661-02	1.4517-01
7.0+00	4.1729-02	1.1290-02	4.8311-02	1.5019-03	6.8231-02	1.8838-02	3.1821-02	3.0019-02	4.0949-03	1.7248-02	6.2442-02
1.0+01	4.1516-02	1.2619-02	4.5841-02	-5.4823-04	6.3021-02	1.9591-02	2.7826-02	2.6104-02	-2.2629-03	1.3525-02	2.3127-02
3.0+01	3.2633-02	1.4139-02	2.9599-02	-6.0618-03	3.7026-02	1.6841-02	1.3692-02	1.2378-02	-1.1379-02	4.8180-03	-1.3133-02
7.0+01	2.0129-02	1.0676-02	1.5330-02	-6.2483-03	1.8178-02	1.0650-02	5.9060-03	5.1203-03	-8.3594-03	1.6664-03	-6.8004-03
1.0+02	1.5192-02	8.6283-03	1.0755-02	-5.4359-03	1.2649-02	8.1136-03	3.9904-03	3.3267-03	-6.3860-03	9.8666-04	-4.2864-03
					$z' = 4 \quad n = 6$						
1.0-02	2.6250-02	1.1148-02	6.5372-02	3.4605-02	8.5877-02	1.4933-02	3.0889-02	3.8571-02	8.1206-02		
3.0-02	3.4480-02	1.4493-02	8.5521-02	4.5098-02	1.1219-01	1.9208-02	4.0216-02	5.0148-02	1.0501-01		
7.0-02	4.2452-02	1.7480-02	1.0445-01	5.4658-02	1.3663-01	2.2887-02	4.8657-02	6.0511-02	1.2536-01		
1.0-01	4.6283-02	1.8703-02	1.1319-01	5.8892-02	1.4776-01	2.4288-02	5.2373-02	6.4998-02	1.3357-01		
3.0-01	5.9723-02	2.1833-02	1.4057-01	7.0457-02	1.8116-01	2.6157-02	6.2404-02	7.6481-02	1.4935-01		
7.0-01	7.0881-02	2.0969-02	1.5579-01	7.2662-02	1.9631-01	2.1315-02	6.4671-02	7.7529-02	1.3659-01		
1.0+00	7.5130-02	1.6884-02	1.5776-01	6.9866-02	1.9595-01	1.6608-02	6.2907-02	7.4349-02	1.2166-01		
3.0+00	8.0540-02	4.0443-03	1.3534-01	4.3666-02	1.5783-01	-4.9844-03	4.6032-02	5.1051-02	5.3764-02		
7.0+00	6.9381-02	-9.6161-03	9.1429-02	1.6288-02	1.0102-01	-1.6241-02	2.7428-02	2.8574-02	1.2863-02		
1.0+01	6.0498-02	-1.2951-02	7.1469-02	7.6665-03	7.7641-02	-1.7109-02	2.0558-02	2.0836-02	3.5485-03		
3.0+01	2.9909-02	-1.2201-02	2.6209-02	3.6007-03	2.7775-02	-1.1393-02	6.7056-03	6.3235-03	4.7942-03		
7.0+01	1.3947-02	-7.3515-03	9.8334-03	3.6242-03	1.0486-02	-5.8574-03	2.4472-03	2.1380-03	3.2235-03		
1.0+02	9.7262-03	-5.5280-03	6.4206-03	2.9984-03	6.8215-03	-4.2545-03	1.5645-03	1.3121-03	2.3792-03		
					$z' = 5 \quad n = 5$						
1.0-02	9.9659-03	1.7497-03	1.3145-02	1.8685-03	2.0116-02	3.6813-03	1.1278-02	1.0759-02	8.6066-03	1.0275-02	4.2201-02
3.0-02	1.3099-02	2.3059-03	1.7279-02	2.4483-03	2.6433-02	4.8466-03	1.4799-02	1.4123-02	1.1261-02	1.3444-02	5.5567-02
7.0-02	1.6167-02	2.8586-03	2.1303-02	2.9997-03	3.2567-02	5.9947-03	1.8202-02	1.7373-02	1.3759-02	1.6421-02	6.8736-02
1.0-01	1.7656-02	3.1316-03	2.3247-02	3.2581-03	3.5522-02	6.5576-03	1.9829-02	1.8922-02	1.4912-02	1.7797-02	7.5178-02
3.0-01	2.3077-02	4.1798-03	3.0225-02	4.1037-03	4.6029-02	8.6607-03	2.5485-02	2.4312-02	1.8513-02	2.2135-02	9.8956-02
7.0-01	2.8127-02	5.3006-03	3.6449-02	4.6409-03	5.5169-02	1.0768-02	3.0070-02	2.8667-02	2.0334-02	2.4631-02	1.2064-01
1.0+00	3.0430-02	5.8946-03	3.9154-02	4.7413-03	5.8963-02	1.1814-02	3.1779-02	3.0268-02	2.0289-02	2.5044-02	1.2919-01
3.0+00	3.7346-02	8.4567-03	4.5945-02	3.8105-03	6.7765-02	1.5658-02	3.3043-02	3.2241-02	1.3876-02	2.2168-02	1.2374-01
7.0+00	4.0464-02	1.1296-02	4.6215-02	8.3287-04	6.4760-02	1.8564-02	2.9730-02	2.8041-02	1.7411-03	1.5711-02	4.7176-02
1.0+01	4.0341-02	1.2537-02	4.4018-02	-1.0233-03	6.0154-02	1.9228-02	2.6240-02	2.4612-02	-3.6217-03	1.2557-02	1.5764-02
3.0+01	3.2020-02	1.3943-02	2.8839-02	-6.0628-03	3.6071-02	1.6526-02	1.3230-02	1.1976-02	-1.1330-02	4.6657-03	-1.3071-02
7.0+01	1.9909-02	1.0663-02	1.5133-02	-6.2139-03	1.7961-02	1.0563-02	5.8728-03	5.0260-03	-8.2330-03	1.6545-03	-6.7612-03
1.0+02	1.5142-02	8.6374-03	1.0686-02	-5.4256-03	1.2538-02	8.0719-03	3.9753-03	3.2997-03	-6.3321-03	9.7938-04	-4.2631-03

TABLE 24 (continued)

KE(Ry)	$s_{1/2}\rightarrow kp_{1/2}$	$s_{1/2}\rightarrow kp_{3/2}$	$p_{1/2}\rightarrow kp_{1/2}$	$p_{1/2}\rightarrow kd$	$p_{3/2}\rightarrow ks_{1/2}$	$p_{3/2}\rightarrow kd$	$d\rightarrow kp_{1/2}$	$d\rightarrow kp_{3/2}$	$d\rightarrow kf$	$f\rightarrow kd$	$f\rightarrow kg$
					$z' = 5$ $n = 6$						
1.0-02	2.4519-02	5.8161-03	5.1465-02	2.2788-02	6.5968-02	5.5154-03	2.4082-02	2.8664-02	4.7417-02		
3.0-02	3.2199-02	7.5555-03	6.7403-02	2.9742-02	8.631?-02	7.0841-03	3.1428-02	3.7380-02	6.1531-02		
7.0-02	3.9637-02	9.0788-03	8.2485-02	3.6148-02	1.0541-01	8.3324-03	3.8213-02	4.5343-02	7.3949-02		
1.0-01	4.3198-02	9.7207-03	8.9501-02	3.9026-02	1.1421-01	8.7718-03	4.1269-02	4.8908-02	7.9176-02		
3.0-01	5.5060-02	1.1099-02	1.1221-01	4.7311-02	1.4187-01	8.8446-03	5.0222-02	5.9028-02	9.1059-02		
7.0-01	6.6018-02	1.0119-02	1.2648-01	4.9939-02	1.5727-01	5.6405-03	5.3815-02	6.2310-02	8.7506-02		
1.0+00	6.9904-02	8.5810-03	1.2951-01	4.8744-02	1.5928-01	-2.8426-03	5.3384-02	6.1173-02	8.0266-02		
3.0+00	7.5425-02	-1.8281-03	1.1723-01	3.2594-02	1.3698-01	-1.0225-02	4.2216-02	4.5985-02	3.9454-02		
7.0+00	6.5999-02	-1.1666-02	8.3834-02	1.2659-02	9.3215-02	-1.7285-02	2.6916-02	2.7709-02	9.4350-03		
1.0+01	5.8016-02	-1.4005-02	6.7153-02	5.7319-03	7.3324-02	-1.7522-02	2.0712-02	2.0808-02	1.8325-03		
3.0+01	2.9350-02	-1.2048-02	2.5839-02	3.9115-03	2.7737-02	-1.1560-02	7.1575-03	6.6322-03	5.2522-03		
7.0+01	1.4107-02	-2.3836-03	1.0036-02	3.7605-03	1.0673-02	-6.0085-03	2.6516-03	2.2862-03	3.4703-03		
1.0+02	9.6833-03	-5.5124-03	6.4509-03	3.0567-03	6.9860-03	-4.3512-03	1.6815-03	1.4150-03	2.5902-03		
					$z' = 6$ $n = 5$						
1.0-02	9.5125-03	1.8680-03	1.2239-02	1.3776-03	1.8437-02	3.8190-03	9.9284-03	9.4344-03	5.9343-03	8.2501-03	4.0884-02
3.0-02	1.2510-02	2.4610-03	1.6089-02	1.8044-03	2.4229-02	5.0267-03	1.3036-02	1.2387-02	7.7614-03	1.0805-02	5.3741-02
7.0-02	1.5440-02	3.0478-03	1.9840-02	2.2089-03	2.9860-02	6.2142-03	1.6042-02	1.5244-02	9.4755-03	1.3228-02	6.6241-02
1.0-01	1.6863-02	3.3371-03	2.1652-02	2.3977-03	3.2571-02	6.7949-03	1.7463-02	1.6609-02	1.0262-02	1.4360-02	7.2269-02
3.0-01	2.2031-02	4.4352-03	2.8169-02	3.0071-03	4.2248-02	8.5920-03	2.2500-02	2.1383-02	1.2698-02	1.8048-02	9.3577-02
7.0-01	2.6855-02	5.5020-03	3.4028-02	3.3673-03	5.0738-02	1.1079-02	2.6658-02	2.5320-02	1.3812-02	2.0449-02	1.1068-01
1.0+00	2.9056-02	6.1766-03	3.6573-02	3.4106-03	5.4302-02	1.2116-02	2.8254-02	2.6824-02	1.3687-02	2.1030-02	1.1656-01
3.0+00	3.5720-02	8.0403-03	4.3164-02	2.4921-03	6.2463-02	1.5798-02	3.0696-02	2.9040-02	8.6340-03	1.9587-02	9.8711-02
7.0+00	3.6809-02	1.1247-02	4.3806-02	-1.4473-04	6.0884-02	1.8447-02	2.7496-02	2.5837-02	8.7982-04	1.4592-02	3.3462-02
1.0+01	3.8779-02	1.2364-02	4.1932-02	-1.7792-03	5.6929-02	1.9013-02	2.4559-02	2.2938-02	-5.1881-03	1.1897-02	9.0830-03
3.0+01	3.1161-02	1.3568-02	2.8004-02	-6.2250-03	3.4939-02	1.6289-02	1.2811-02	1.1553-02	-1.1343-02	4.6448-03	-1.3244-02
7.0+01	1.9708-02	1.0584-02	1.4838-02	-6.1984-03	1.7638-02	1.0436-02	5.7677-03	4.9441-03	-8.1768-03	1.6656-03	-6.8257-03
1.0+02	1.5127-02	8.6971-03	1.0516-02	-5.3941-03	1.2406-02	8.0067-03	3.9539-03	3.2699-03	-6.3281-03	9.9998-04	-4.3595-03
					$z' = 7$ $n = 5$						
1.0-02	9.0909-03	2.1061-03	1.1145-02	8.1055-04	1.6566-02	3.9571-03	8.5936-03	8.0963-03	3.3633-03	6.8972-03	3.6333-02
3.0-02	1.1955-02	2.7761-03	1.4653-02	1.0603-03	2.1773-02	5.2070-03	1.1286-02	1.0634-02	4.3955-03	9.0402-03	4.7675-02
7.0-02	1.4754-02	3.4347-03	1.8070-02	1.2946-03	2.6836-02	6.4341-03	1.3894-02	1.3089-02	5.3555-03	2.8588-02	5.8579-02
1.0-01	1.6115-02	3.7586-03	1.9724-02	1.4024-03	2.9280-02	7.0328-03	1.5146-02	1.4269-02	5.7918-03	1.2049-02	6.3755-02
3.0-01	2.1060-02	4.9479-03	2.5681-02	1.7345-03	3.8024-02	9.2434-03	1.9546-02	1.8414-02	7.0870-03	1.5264-02	8.1679-02
7.0-01	2.5685-02	6.2155-03	3.1068-02	1.8811-03	4.5764-02	1.1389-02	2.3262-02	2.1904-02	7.5287-03	5.5445-02	9.3635-02
1.0+00	2.7803-02	6.8429-03	3.3432-02	1.8524-03	4.9061-02	1.2417-02	2.4734-02	2.3276-02	7.3047-03	1.8197-02	9.5917-02
3.0+00	3.4274-02	9.3234-03	3.9738-02	9.1976-04	5.6999-02	1.5941-02	2.7376-02	2.5690-02	3.6856-03	1.7690-02	7.2215-02
7.0+00	3.7429-02	1.1168-02	4.0795-02	-1.3440-03	5.6420-02	1.8327-02	2.5176-02	2.3475-02	-3.7007-03	1.3791-02	2.0937-02
1.0+01	3.7518-02	1.2807-02	3.9318-02	-2.7239-03	5.3219-02	1.8801-02	2.2789-02	2.1145-02	-6.9658-03	1.1475-02	2.7654-03
3.0+01	3.0544-02	1.3750-02	2.6941-02	-6.4496-03	3.3696-02	1.6073-02	1.2415-02	1.1142-02	-1.1459-02	4.7256-03	-1.3690-02
7.0+01	2.9457-02	1.0540-02	1.4537-02	-6.2188-03	1.7392-02	1.0374-02	5.7774-03	4.8899-03	-8.2017-03	1.7340-03	-7.0639-03
1.0+02	1.4903-02	8.5803-03	1.0380-02	-5.3969-03	1.2339-02	7.9908-03	3.9752-03	3.2622-03	-6.3499-03	1.0528-03	-4.5487-03

TABLE 24 (continued)

KE(Ry)	$s_{1/2}\rightarrow kp_{1/2}$	$s_{1/2}\rightarrow kp_{3/2}$	$p_{1/2}\rightarrow kp_{1/2}$	$p_{1/2}\rightarrow kd$	$p_{3/2}\rightarrow ks_{1/2}$	$p_{3/2}\rightarrow kd$	$d\rightarrow kp_{1/2}$	$d\rightarrow kp_{3/2}$	$d\rightarrow kf$	$f\rightarrow kd$	$f\rightarrow kg$
					$z' = 8$ $n = 5$						
1.0-02	8.7632-03	2.1093-03	1.0626-02	6.3734-04	1.5552-02	3.8911-03	7.8120-03	7.3675-03	2.4353-03	5.6639-03	3.0177-02
3.0-02	1.1525-02	2.7774-03	1.3969-02	8.3308-04	2.0440-02	5.1198-03	1.0262-02	9.6790-03	3.1792-03	7.4291-03	3.9522-02
7.0-02	1.4225-02	3.4358-03	1.7228-02	1.0157-03	2.5196-02	6.3254-03	1.2635-02	1.1917-02	3.8678-03	9.1200-03	4.8376-02
1.0-01	1.5537-02	3.7591-03	1.8806-02	1.0991-03	2.7494-02	6.9138-03	1.3777-02	1.2990-02	4.1776-03	9.9191-03	5.2501-02
3.0-01	2.0312-02	4.9698-03	2.4492-02	1.3483-03	3.5720-02	9.0811-03	1.7805-02	1.6785-02	5.0682-03	1.2527-02	6.5718-02
7.0-01	2.4774-02	6.1936-03	2.9648-02	1.4343-03	4.3034-02	1.1176-02	2.1230-02	1.9998-02	5.2742-03	1.4635-02	7.3001-02
1.0+00	2.6810-02	6.8097-03	3.1917-02	1.3373-03	4.6179-02	1.2175-02	2.2600-02	2.1284-02	5.0210-03	1.5281-02	7.3346-02
3.0+00	3.3040-02	9.2019-03	3.8038-02	4.7784-04	5.3876-02	1.5564-02	2.5242-02	2.3678-02	1.5792-03	1.5309-02	5.4438-02
7.0+00	3.6167-02	1.1531-02	3.9215-02	-1.6241-03	5.3693-02	1.7824-02	2.3528-02	2.1917-02	-4.4880-03	1.2339-02	1.2650-02
1.0+01	3.6317-02	1.2480-02	3.7905-02	-2.9006-03	5.0871-02	1.8270-02	2.1456-02	1.9085-02	-7.3068-03	1.0424-02	-1.1420-03
3.0+01	2.9177-02	1.3353-02	2.6268-02	-6.3724-03	3.2728-02	1.5663-02	1.2017-02	1.0773-02	-1.1214-02	4.4442-03	-1.3303-02
7.0+01	1.9226-02	1.0408-02	1.4328-02	-6.1498-03	1.7084-02	1.0212-02	5.6488-03	4.8100-03	-8.0782-03	1.6810-03	-6.8557-03
1.0+02	1.4818-02	8.5745-03	1.0248-02	-5.3493-03	1.2125-02	7.8833-03	3.8538-03	3.1836-03	-6.2505-03	1.0181-03	-4.4206-03
					$z' = 9$ $n = 5$						
1.0-02	9.3476-03	2.1858-03	9.8121-03	3.1886-04	1.4231-02	3.8962-03	6.9449-03	6.5222-03	1.1698-03	4.8280-03	2.1891-02
3.0-02	1.0979-02	2.6776-03	1.2902-02	4.1516-04	1.8707-02	5.1261-03	9.1250-03	8.5698-03	1.5220-03	6.3349-03	2.8631-02
7.0-02	1.3552-02	3.5585-03	1.5913-02	5.0214-04	2.3064-02	6.3319-03	1.1242-02	1.0555-02	1.8380-03	7.7822-03	3.4960-02
1.0-01	1.4801-02	3.8920-03	1.7371-02	5.3996-04	2.5168-02	6.9190-03	1.2258-02	1.1508-02	1.9744-03	8.4710-03	3.7877-02
3.0-01	1.9354-02	5.1362-03	2.2636-02	6.3320-04	3.2726-02	9.0792-03	1.5865-02	1.4889-02	2.2988-03	1.0829-02	4.6868-02
7.0-01	2.3615-02	6.3794-03	2.7431-02	5.9919-04	3.9489-02	1.1152-02	1.8974-02	1.7799-02	2.1506-03	1.2651-02	5.1021-02
1.0+00	2.5571-02	6.9972-03	2.9555-02	5.1199-04	4.2413-02	1.2133-02	2.0253-02	1.8981-02	1.8297-03	1.3281-02	5.0594-02
3.0+00	3.1605-02	9.3373-03	3.5403-02	-3.9766-04	4.9846-02	1.5404-02	2.2494-02	2.1398-02	1.1410-03	1.3690-02	3.3139-02
7.0+00	3.4702-02	1.1525-02	3.6806-02	-2.2644-03	5.0228-02	1.7519-02	2.1749-02	2.0177-02	6.0045-03	1.1427-02	5.2182-03
1.0+01	3.4906-02	1.2394-02	3.5759-02	-3.3791-03	4.7887-02	1.7918-02	2.0027-02	1.8479-02	8.2591-03	9.8166-03	-4.8915-03
3.0+01	2.6985-02	1.3134-02	2.5337-02	-6.4101-03	3.1528-02	1.5384-02	1.1576-02	1.0346-02	-1.1186-02	4.3955-03	-1.3357-02
7.0+01	1.6969-02	1.0325-02	1.4121-02	-6.1467-03	1.6755-02	1.0078-02	5.5560-03	4.7165-03	-8.0235-03	1.6861-03	-6.9198-03
1.0+02	1.4732-02	8.5642-03	1.0171-02	-5.3582-03	1.2000-02	7.8137-03	3.8194-03	3.1515-03	-6.2055-03	1.0372-03	-4.4848-03
					$z' = 10$ $n = 5$						
1.0-02	8.1484-03	2.2743-03	9.3888-03	1.7529-04	1.3370-02	3.8053-03	6.3433-03	5.9821-03	5.8163-04	4.0726-03	1.5053-02
3.0-02	1.0717-02	2.9936-03	1.2344-02	2.2018-04	1.7575-02	5.0062-03	8.3346-03	7.8602-03	7.5160-04	5.3456-03	1.9675-02
7.0-02	1.3226-02	3.7023-03	1.5232-02	2.6247-04	2.1672-02	6.1832-03	1.0266-02	9.6845-03	8.9474-04	6.5730-03	2.3997-02
1.0-01	1.4444-02	4.0488-03	1.6623-02	2.7906-04	2.3658-02	6.7566-03	1.1196-02	1.0562-02	9.5029-04	7.1576-03	2.5967-02
3.0-01	1.8890-02	5.3381-03	2.1668-02	2.9920-04	3.0765-02	8.8633-03	1.4503-02	1.3676-02	1.0132-03	9.1748-03	3.1941-02
7.0-01	2.3055-02	6.6191-03	2.6261-02	2.0847-04	3.7142-02	1.0879-02	1.7275-02	1.6369-02	7.0394-04	1.0779-02	3.4411-02
1.0+00	2.4965-02	7.2502-03	2.8303-02	1.0202-04	3.9915-02	1.1832-02	1.8561-02	1.7475-02	-3.5460-04	1.1358-02	3.3861-02
3.0+00	3.0891-02	9.6145-03	3.3979-02	-8.1016-04	4.7190-02	1.4988-02	2.1128-02	1.9824-02	-2.3640-03	1.1937-02	2.0810-02
7.0+00	3.3975-02	1.1768-02	3.5457-02	-2.5663-03	4.7749-02	1.7011-02	2.0256-02	1.8865-02	-6.5919-03	1.0209-02	3.1435-04
1.0+01	3.4236-02	1.2607-02	3.4521-02	-3.6011-03	4.6691-02	1.7391-02	1.8767-02	1.7373-02	-8.5401-03	8.8707-03	-7.2410-03
3.0+01	2.8452-02	1.3169-02	2.8639-02	-6.3816-03	3.0508-02	1.4992-02	1.1026-02	9.8788-03	-1.0913-02	4.1164-03	-1.2919-02
7.0+01	1.8536-02	1.0104-02	1.3751-02	-6.0257-03	1.8336-02	9.8658-03	5.4050-03	4.5665-03	-7.8048-03	1.6330-03	-6.6886-03
1.0+02	1.4307-02	8.2743-03	9.9311-03	-5.2421-03	1.1727-02	7.6579-03	3.7571-03	3.1015-03	-6.0879-03	9.9536-04	-4.3365-03

TABLE 24 (continued)

KE(Ry)	$s_{1/2}\rightarrow kp_{1/2}$	$s_{1/2}\rightarrow kp_{3/2}$	$P_{1/2}\rightarrow kp_{1/2}$	$P_{1/2}\rightarrow kd$	$P_{3/2}\rightarrow ks_{1/2}$	$P_{3/2}\rightarrow kd$	$d\rightarrow kp_{1/2}$	$d\rightarrow kp_{3/2}$	$d\rightarrow kf$	$f\rightarrow kd$	$f\rightarrow kg$
					$z' = 11$ $n = 5$						
1.0-02	7.7703-03	2.2516-03	8.8222-03	-2.7215-06	1.2385-02	3.7005-03	5.7290-03	5.3920-03	5.1584-06	3.5067-03	9.5798-03
3.0-02	1.0220-02	2.9636-03	1.1600-02	-3.0727-07	1.6283-02	4.8687-03	7.5282-03	7.0850-03	-3.5408-06	4.6043-03	1.2517-02
7.0-02	1.2616-02	3.6639-03	1.4309-02	-7.6842-06	2.0076-02	6.0142-03	9.2760-03	8.7293-03	-2.9727-05	5.6648-03	1.5246-02
1.0-01	1.3779-02	4.0059-03	1.5622-02	-1.4978-05	2.1910-02	6.5706-03	1.0119-02	9.5218-03	-5.3124-05	6.1703-03	1.6485-02
3.0-01	1.6022-02	5.2775-03	2.0370-02	-7.6514-05	2.8523-02	8.6139-03	1.3121-02	1.2341-02	-2.4624-04	7.9302-03	2.0157-02
7.0-01	2.2006-02	6.5330-03	2.4713-02	-2.2926-04	3.4473-02	1.0565-02	1.5755-02	1.4802-02	-7.1200-04	9.3603-03	2.1422-02
1.0+00	2.3839-02	7.1496-03	2.6649-02	-3.5587-04	3.7078-02	1.1484-02	1.6855-02	1.5826-02	-1.0872-03	9.8969-03	2.0850-02
3.0+00	2.9526-02	9.4205-03	3.2089-02	-1.2594-03	4.3959-02	1.4504-02	1.9359-02	1.8107-02	-3.5463-03	1.0602-02	1.1226-02
7.0+00	3.2555-02	1.1447-02	3.3675-02	-2.8722-03	4.4942-02	1.6421-02	1.8824-02	1.7464-02	-7.1325-03	9.2991-03	-3.6392-03
1.0+01	3.2851-02	1.2227-02	3.2907-02	-3.8091-03	4.3252-02	1.6783-02	1.7583-02	1.6215-02	-8.7694-03	8.1866-03	-9.1959-03
3.0+01	2.7621-02	1.2729-02	2.3856-02	-6.3285-03	2.9510-02	1.4567-02	1.0663-02	9.5208-03	-1.0730-02	3.9484-03	-1.2687-02
7.0+01	1.8288-02	1.0022-02	1.3512-02	-5.9715-03	1.6048-02	9.7702-03	5.2770-03	4.4948-03	-7.7138-03	1.5955-03	-6.5660-03
1.0+02	1.4233-02	8.3036-03	9.8015-03	-5.2036-03	1.1643-02	7.6105-03	3.6554-03	3.0283-03	-5.9981-03	9.8441-04	-4.2752-03
					$z' = 12$ $n = 5$						
1.0-02	7.4286-03	2.2582-03	8.3461-03	-2.0220-04	1.1506-02	3.6410-03	5.1933-03	4.8841-03	-4.9583-04	3.0587-03	5.5919-03
3.0-02	9.7763-03	2.9721-03	1.0974-02	-2.6875-04	1.5126-02	4.7894-03	6.8206-03	6.4185-03	-6.6001-04	4.0163-03	7.2992-03
7.0-02	1.2060-02	3.6733-03	1.3537-02	-3.3870-04	1.8654-02	5.9138-03	8.4051-03	7.9103-03	-8.3396-04	4.9418-03	8.8721-03
1.0-01	1.3173-02	4.0160-03	1.4780-02	-3.7566-04	2.0361-02	6.4613-03	9.1692-03	8.6302-03	-9.2674-04	5.3852-03	9.5775-03
3.0-01	1.7252-02	5.2866-03	1.9281-02	-5.4078-04	2.6518-02	8.4689-03	1.1803-02	1.1195-02	-1.3479-03	6.9369-03	1.1580-02
7.0-01	2.1042-02	6.5347-03	2.3404-02	-7.7836-04	3.2087-02	1.0381-02	1.4310-02	1.3454-02	-1.9624-03	8.2213-03	1.1996-02
1.0+00	2.2798-02	7.1432-03	2.5253-02	-9.3714-04	3.4540-02	1.1281-02	1.5331-02	1.4403-02	-2.3700-03	8.7189-03	1.1404-02
3.0+00	2.8288-02	9.3578-03	3.0495-02	-1.8794-03	4.1118-02	1.4221-02	1.7747-02	1.6602-02	-4.6576-03	9.4942-03	4.1719-03
7.0+00	3.1272-02	1.1298-02	3.2166-02	-3.3898-03	4.2360-02	1.6064-02	1.7463-02	1.6209-02	-7.7315-03	8.5138-03	-6.6506-03
1.0+01	3.1617-02	1.2015-02	3.1517-02	-4.2389-03	4.0921-02	1.6408-02	1.6421-02	1.5149-02	-9.1031-03	7.5840-03	-1.0704-02
3.0+01	2.6846-02	1.2501-02	2.3018-02	-6.4025-03	2.8348-02	1.4244-02	1.0194-02	9.0938-03	-1.0547-02	3.7996-03	-1.2469-02
7.0+01	1.7997-02	9.8809-03	1.3028-02	-5.8483-03	1.5620-02	9.5397-03	5.1366-03	4.3566-03	-7.5801-03	1.5689-03	-6.4683-03
1.0+02	1.4077-02	8.2425-03	9.5289-03	-5.0827-03	1.1346-02	7.4553-03	3.6065-03	2.9789-03	-5.9102-03	9.7501-04	-4.2404-03

EXIT CALLED FROM 014217

For bound-bound transitions with $n' \geq 8$, we obtain r in Eq. (93) from

$$r = \frac{2z'^2}{\pi n^{*'3}} \left(\frac{Ry}{KE_1}\right)^{\frac{1}{2}} \sigma^2(KE_1) \quad , \tag{B-20}$$

where $\sigma(KE_1)$ is given in Table 24 and KE_1, the lowest photoelectron kinetic energy at which the STF values of σ are evaluated, is much less than the binding energy of the jumping electron in the initial state.

FREE-FREE TRANSITIONS

The free-free contribution to the opacity is given by

$$\kappa_{ff} = \frac{64}{3\sqrt{3}} \pi \frac{N_0}{A} \alpha \, a_0^2 \frac{\overline{z^2}}{\Gamma} \left(\frac{Ry}{\theta}\right)^2 u^{-3} \quad . \tag{B-21}$$

APPENDIX C

CALCULATION OF TRANSMISSION BY A LINE CLUSTER

The mean transmission by a line cluster over a frequency interval $\delta u = \Delta$ centered at u is

$$\overline{T}(u) = \frac{1}{\Delta} \int_{u-(\Delta/2)}^{u+(\Delta/2)} T(u - u_0)\, du \,, \qquad (C-1)$$

where u_0 is the frequency of the cluster center and $T(u - u_0) = T_j(m, u)$ is given by Eq. (107). The calculation of $\overline{T}$ is somewhat difficult in the case that $T(u - u_0)$ and $A = 1 - T(u - u_0)$ vary significantly in the interval; otherwise, the calculation is relatively simple.

When T and A do change significantly over an interval, the greatest variation of $T(u - u_0)$ occurs, in general, in the interval containing the cluster center, $u = u_0$. When T varies from nearly zero at the center to nearly one at the edge, T remains near unity in intervals not containing the cluster center. Similarly, T in off-center intervals does not vary greatly with u so long as the same thing is true for the interval containing the cluster center.

The foregoing remarks provide the basis for our calculation of $\overline{T}$ in all off-center intervals. In this case we perform the integration in Eq. (C-1) after linearly interpolating $\ln T(u - u_0)$ between the interval's end points. The result is

$$\overline{T} = \frac{1}{\Delta} \int \left[\frac{d(\ln T)}{du}\right]^{-1} dT \approx \frac{T\left(u - u_0 + \frac{\Delta}{2}\right) - T\left(u - u_0 - \frac{\Delta}{2}\right)}{\ln \dfrac{T\left(u - u_0 + \frac{\Delta}{2}\right)}{T\left(u - u_0 - \frac{\Delta}{2}\right)}} . \qquad (C-2)$$

For the average transmission in the central interval there are two cases to consider. If practically all of the frequency-integrated absorption comes from the central interval, we can estimate $\overline{T}$ accurately from the curve of growth. If this is not the case, we subdivide the central interval into a number M of intervals and numerically integrate by summing the contribution from each subinterval. This contribution is obtained from Eq. (C-2) by replacing Δ by Δ/M.

The curve of growth is defined by

$$W(a, \tau_0) = \frac{1}{D} \int_{-\infty}^{\infty} [1 - T(u)] \, du \, , \tag{C-3}$$

where D is the Gaussian cluster width in units of θ and

$$\tau_0 = N \overline{\tau} \tag{C-4}$$

We require

$$\overline{T} = \frac{1}{\Delta} \left\{ \Delta - \int_{-\Delta/2}^{\Delta/2} [1 - T(u)] \, du \right\}$$

$$\approx 1 - \frac{D}{\Delta} W(a, \tau_0) \, . \tag{C-5}$$

When the number of lines N is large, $W(a, \tau_0)$ is formally equivalent to the curve of growth of a Doppler-broadened Lorentz line. Numerical calculations of the latter curve of growth have been made by Hummer.[20] We find that Hummer's results can be fitted extremely well by a weighted root mean square of the purely Doppler and purely Lorentz curves of growth.[30] If we introduce

$$W^*(a, \tau_0) = \pi^{-\frac{1}{2}} H(a, 0) \, W(a, \tau_0) \, , \tag{C-6}$$

then

$$W^*(a, \tau_0) \approx \left\{ \pi^{\frac{1}{2}} a H(a, 0) \, [W_L^*(\tau_0)]^2 + [1 - \pi^{\frac{1}{2}} a H(a, 0)] \, [W_D^*(\tau_0)]^2 \right\}^{\frac{1}{2}} \, . \tag{C-7}$$

Here

$$W_L^*(\tau_0) = 2L(\tau_0/2) \ , \qquad \text{(C-8)}$$

where L(x) is the tabulated Ladenburg-Reiche function.[17] This function is well approximated by

$$L(x) = x\left(\frac{1 + x}{1 + 1.8x + 1.57x^2}\right)^{\frac{1}{2}} \ . \qquad \text{(C-9)}$$

The function

$$W_D^*(\tau_0) = 2\pi^{-\frac{1}{2}} F(\eta) \qquad \text{(C-10)}$$

can be obtained from the tables of

$$F(\tau_0) = \int_0^\infty [1 - \exp(-\tau_0 e^{-x^2})] \, dx \ . \qquad \text{(C-11)}$$

given by Araki.[31] The values of $F(\tau_0)$ in Table 25 are taken from Araki. For $\tau_0 < 1$, we use

$$F(\tau_0) = \tfrac{1}{2}\pi^{\frac{1}{2}} \tau_0 \left[1 - \tau_0/2\sqrt{2} + \tau_0^2/6\sqrt{3} - \tau_0^3/48 + \tau_0^4/120\sqrt{5}\right] , \qquad \text{(C-12)}$$

and for $\tau_0 > 10$, we use

$$F(\tau_0) = (\ln \tau_0)^{\frac{1}{2}} \left[1 + 0.2886 (\ln \tau_0)^{-1}\right] \ . \qquad \text{(C-13)}$$

Finally, to evaluate (C-2), we require Eq. (107) and the Voigt function, Eq. (112). For speed of calculation we make the following fit (good to about 20% at worst) to the Voigt function:

$$H(a, x) = \left[e^{-x^2} + \beta(x)a\right] \left\{1 + \tau^{\frac{1}{2}} a \left[e^{-x^2} + \beta(x)a\right]\right\}^{-1} \qquad \text{C-14)}$$

$$\beta(x) = 2H(\tfrac{1}{2}, x)\left[1 - \tfrac{1}{2}\pi^{\frac{1}{2}} H(\tfrac{1}{2}, x)\right]^{-1} - 2e^{-x^2} \ . \qquad \text{(C-15)}$$

TABLE 25

THE FUNCTION $F(\tau_0)$

τ_0	$F(\tau_0)$	τ_0	$F(\tau_0)$
1.0	0.643	6.0	1.482
1.5	0.839	6.5	1.511
2.0	0.986	7.0	1.538
2.5	1.099	7.5	1.562
3.0	1.189	8.0	1.584
3.5	1.261	8.5	1.604
4.0	1.320	9.0	1.623
4.5	1.370	9.5	1.641
5.0	1.412	10.0	1.657
5.5	1.449		

TABLE 26

THE FUNCTION $U(\frac{1}{2}, x) = \pi^{-\frac{1}{2}} H(\frac{1}{2}, x)$

x	$U(\frac{1}{2}, x)$	x	$U(\frac{1}{2}, x)$
0	3.4737-01	2.60	2.9837-02
0.20	3.3937-01	2.80	2.4785-02
0.40	3.1665-01	3.00	2.0946-02
0.60	2.8270-01	3.20	1.7969-02
0.80	2.4227-01	3.40	1.5611-02
1.00	2.0023-01	3.60	1.3708-02
1.20	1.6059-01	3.80	1.2147-02
1.40	1.2596-01	4.00	1.0847-02
1.60	9.7503-02	4.20	9.7510-03
1.80	7.5200-02	4.40	8.8179-03
2.00	5.8314-02	4.60	8.0158-03
2.20	4.5802-02	4.80	7.3207-03
2.40	3.6610-02	5.00	6.7140-03

The values of $\pi^{-\frac{1}{2}}H(\frac{1}{2}, x)$ in Table 26 are taken from Hummer's tabulation.[20] For $x > 5$, we use

$$H(\tfrac{1}{2}, x) = \frac{a}{\pi^{\frac{1}{2}}x^2} \quad . \tag{C-16}$$

APPENDIX D

OVERALL PLANCK AND ROSSELAND MEAN OPACITIES

The overall Planck and Rosseland mean opacities, respectively, including the corrections for induced emission, are given by

$$\kappa_p = \frac{15}{\pi^4} \int_0^\infty u^3 e^{-u} \kappa_p(u)\, du \qquad \text{(D-1)}$$

and

$$(\kappa_R)^{-1} = \frac{15}{4\pi^4} \int_0^\infty u^4 e^{-u} \left(1 - e^{-u}\right)^{-3} \kappa_R^{-1}(u)\, du \ . \qquad \text{(D-2)}$$

The values of these quantities both with and without line absorption are included in Table 17. Their behavior as a function of temperature at constant pressure have been given in Figs. 3 and 4.

In performing the numerical calculations required to evaluate κ_p and κ_R we replace the upper limit of integration by $u_{max} < \infty$, where u_{max} is chosen so that the contribution to κ_p from the internal $u_{max} < u < \infty$ is almost certainly less than a small fraction R of κ_p (in the calculation we chose R = 0.05). We shall also show that the relative contribution to κ_R from the interval $u_{max} \leq u < \infty$ is almost certainly less than the quantity ERKROS shown in the tabulation of the local Planck and Rosseland mean opacities.

Our present aim is to find a u_{max} such that the quantity δ_p defined by

$$\int_{u_{max}}^\infty \kappa(u)\, B(u)\, du = \delta_p \int_0^\infty \kappa(u)\, B(u)\, du \qquad \text{(D-3)}$$

is less than the given number $R \ll 1$ (here we take $B(u) = 15\pi^{-4} u^3 e^{-u}$). For this purpose we shall (1) invoke the sum rule[32]

$$\int_0^\infty \kappa(u)\, du = \frac{\pi e^2}{mc} \frac{Z}{Am_H} \frac{h}{\Theta} \qquad \text{(D-4)}$$

to obtain an overestimate of the quantity on the left-hand side of (D-3) and (2) replace $\kappa(u)$ by $\kappa_c(u)$ to obtain an underestimate of the right-hand side of the inequality. In (D-4), m_H and m are the hydrogenic and electronic masses, respectively. If $u_{max} \gtrsim 4$, we may write

$$\int_{u_{max}}^\infty \kappa(u)\, B(u)\, du < B(u_{max}) \int_{u_{max}}^\infty \kappa(u)\, du$$

$$< B(u_{max}) \int_0^\infty \kappa(u)\, du$$

$$< B(u_{max}) \frac{\pi e^2}{mc} \frac{Z}{Am_H} \frac{h}{\theta} .$$

To obtain

$$\int_0^\infty \kappa_c(u)\, B(u)\, du = \frac{15}{\pi^4} \dot{D}_{ff} (1 + u_1) , \qquad \text{(D-6)}$$

we have used the Raiser approximation[33]

$$\left.\begin{aligned} \kappa_c(u) &= D_{ff} \frac{e^u}{u^3} \qquad u \le u_1 \\ &= D_{ff} \frac{e^{u_1}}{u^3} \qquad u > u_1 \end{aligned}\right\} \qquad \text{(D-7)}$$

where $u_1 = I_d/\theta$, with I_d the ionization potential of the dominant ion species, and

$$D_{ff} = \frac{\overline{z^2}}{Am_H} \left(\frac{Ry}{\theta}\right)^2 \frac{1}{\Gamma} \frac{64\pi}{3\sqrt{3}} \alpha a_0^2 \ . \qquad \text{(D-8)}$$

Finally, for a given value of R we can find u_{max} such that

$$\delta_p < R = \frac{3\sqrt{3}}{16} \pi \left(\frac{\theta}{Ry}\right) \frac{z}{\overline{z^2}} \Gamma \frac{u_{max}^3 \exp(-u_{max})}{u_1 + 1} \ . \qquad \text{(D-9)}$$

By similar arguments we can determine that the contribution to the Rosseland mean from the interval $u_{max} \leq u < \infty$ is less than

$$\text{ERKROS} = \frac{15}{8\pi^4} \frac{\kappa_R}{D_{ff}} u_1^7 \left[\exp(-2u_{max}) - \exp(-2u_1) + 2\exp(-2u_1)\, G(u_1)\right]$$

$$u_{max} < u_1$$

$$= \frac{15}{4\pi^4} \frac{\kappa_R}{D_{ff}} u_{max}^7 \exp[-(u_1 + u_{max})]\, G(u_{max})$$

$$u_{max} \geq u_1, \qquad \text{(D-10)}$$

where

$$G(u) = u^{-7} \int_u^\infty x^7 e^{-x}\, dx \ . \qquad \text{(D-11)}$$

APPENDIX E

DESCRIPTION OF THE HALIDE PROGRAM

The diagrams of Figs. 8 and 9 show the relationship of the routines to one another and the flow of the calculations.

The HALIDE block diagram (Fig. 8) illustrates all of the routines, function routines, drums, and input-data tape necessary for the calculation of composition, thermodynamic properties, and opacity. The double-ended arrows indicate that information flows in two directions.

The HALIDE flow diagram (Fig. 9) shows the basic structure of the program; for more detailed information the reader is referred to the program listing at the end of this Appendix. Input parameters and output variables are given before the program listing.

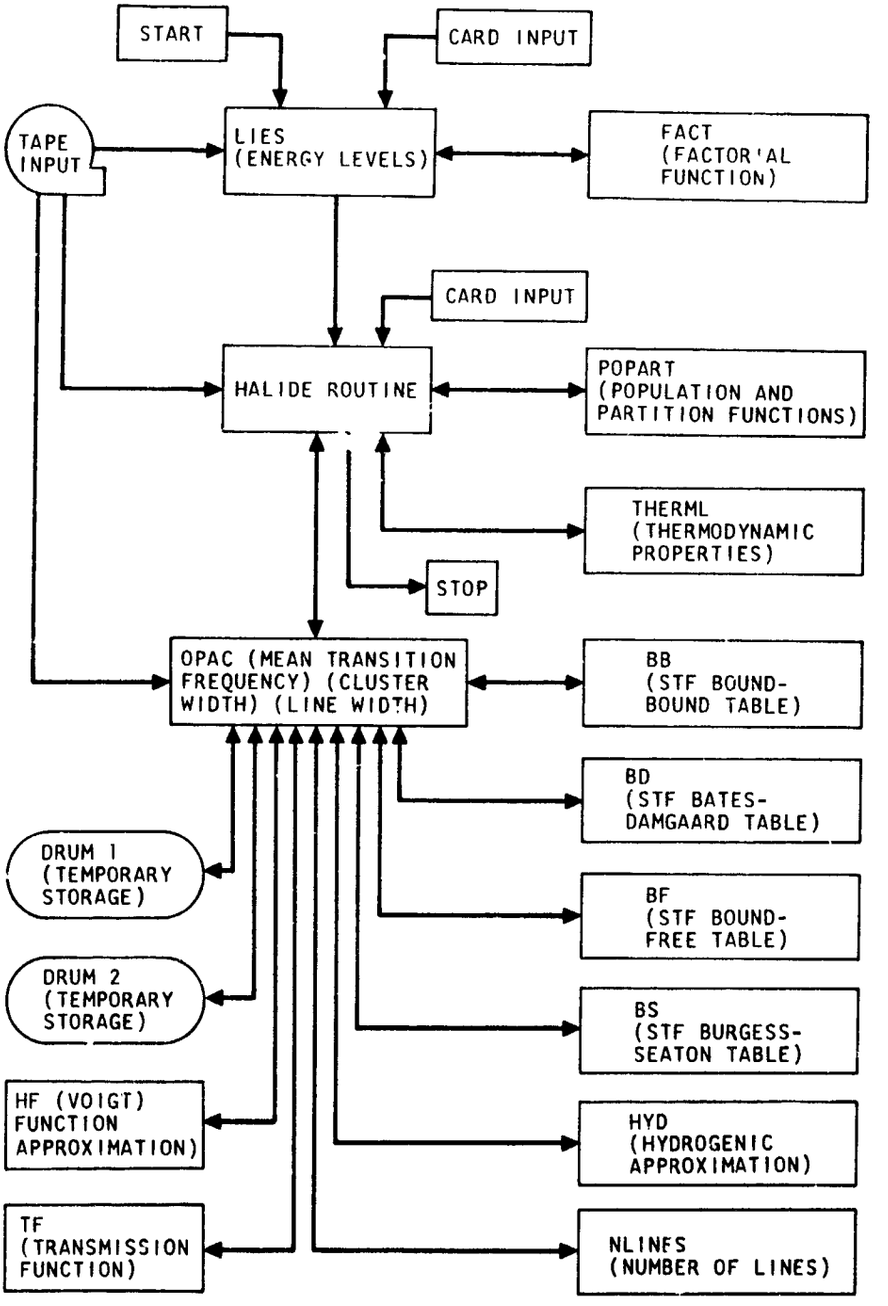


Fig. 8. HALIDE block diagram

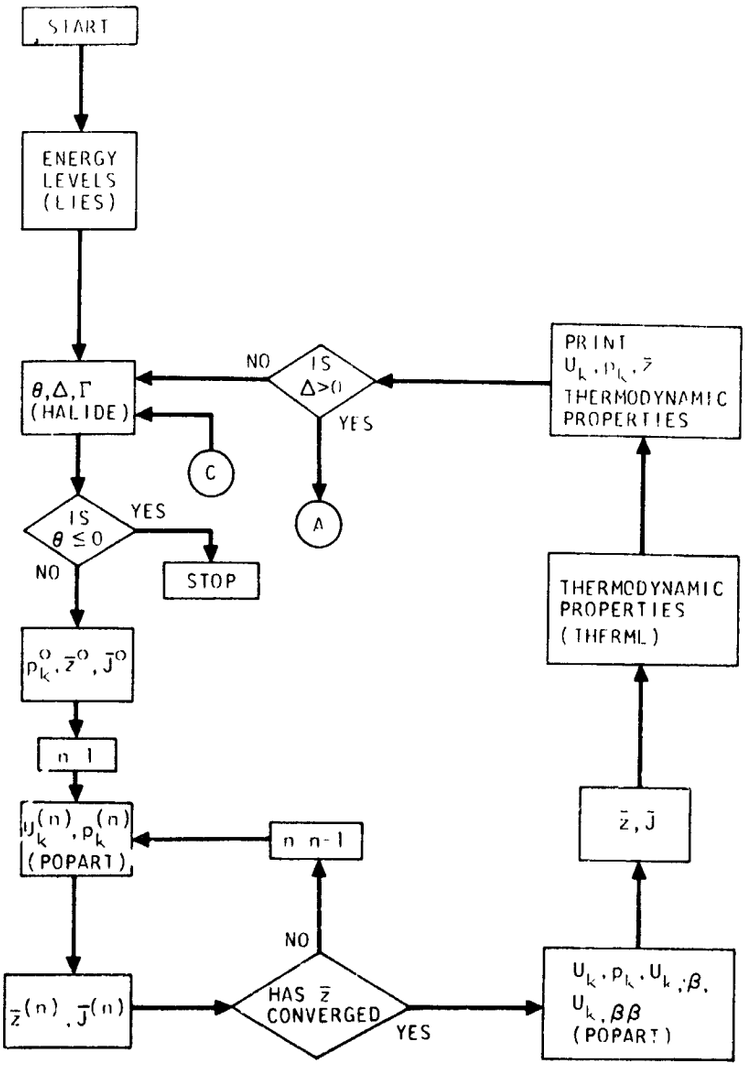


Fig. 9. HALIDE flow diagram (sheet 1 of 3)

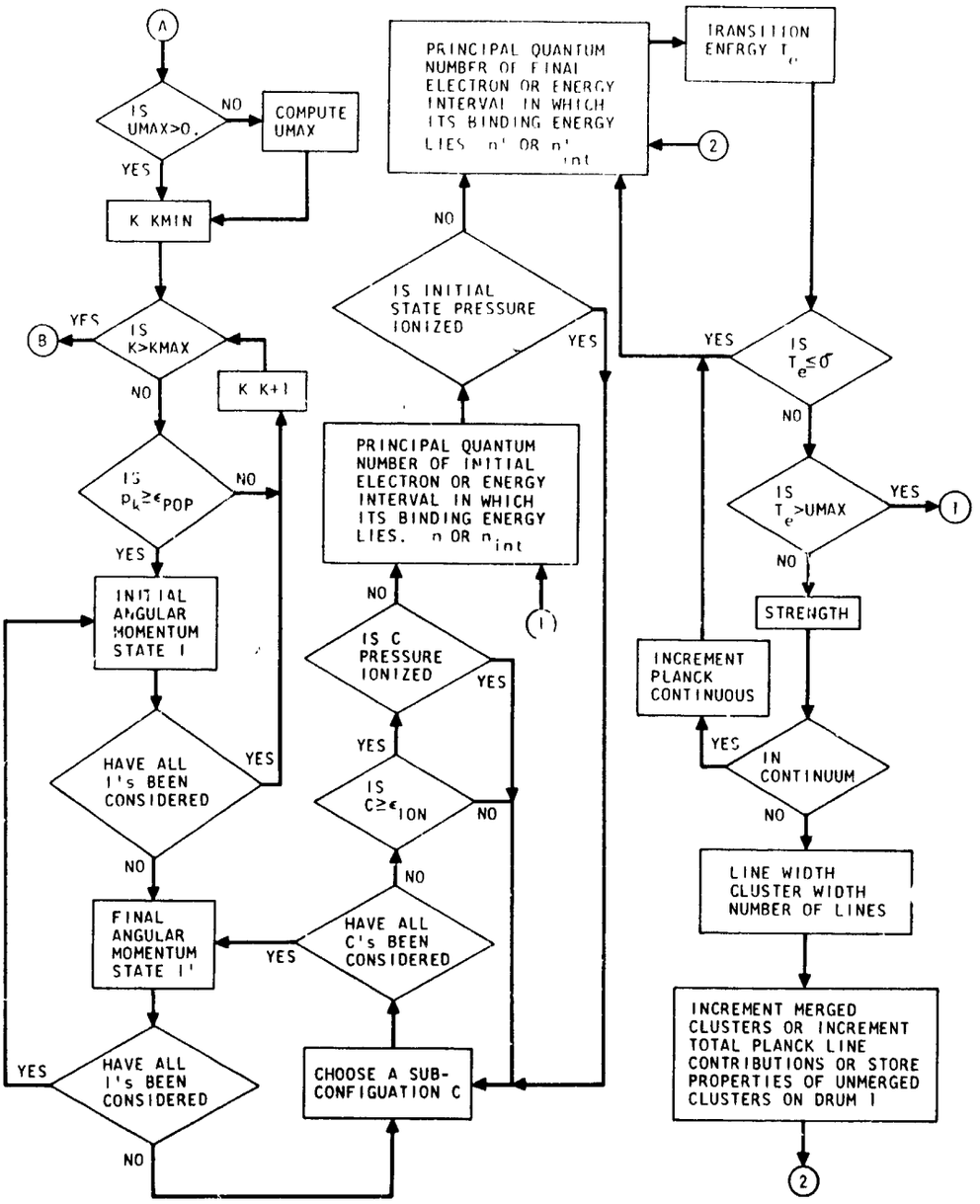


Fig. 9. HALIDE flow diagram (sheet 2 of 3)

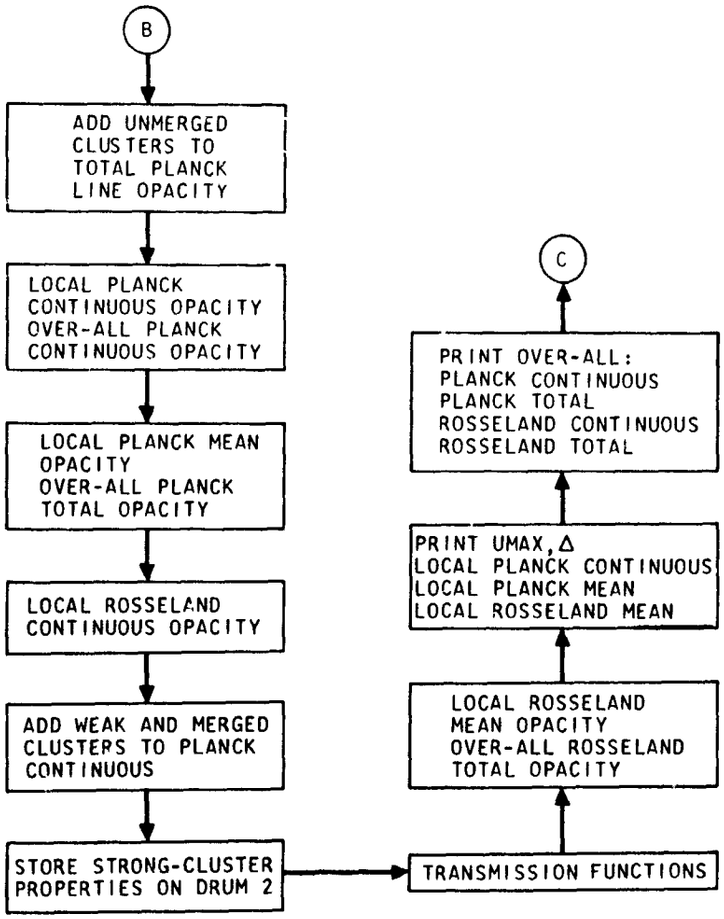


Fig. 9. HALIDE flow diagram (sheet 3 of 3)

DEFINITION OF INPUT PARAMETERS

The terms primary and secondary refer to the sets of subconfigurations associated with an ion. The primary sets are listed in Table 9 and the secondary sets differ from them only in that each of its subconfigurations has one less electron. For UI, for example, the secondary configurations turn out to be the same as the primary configurations for UII (see Table 9).

LIES Data Cards Input

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
NZI	Z	Atomic number of uranium
HEAD(12)		An alphanumeric array that stores 72 character "title" messages

LIES Data Tape Input

NZT	Z	Atomic number of uranium
NP		Maximum number of M shells
NUMZCS		Maximum number of ions
MORB(6)		Maximum number of electrons that can be put in orbital i (i = 1, . . . , NP)
KZC(12, 3)		An array that contains the indices necessary to relate an ion to its primary and secondary sets of subconfigurations
EN(1200)		An array that contains the following for each ion: Z, core charge, ionization potential (ev), the subconfiguration with the least mean energy, eigenvalues for the occupied shells (Ry), f's (Ry), Slater integrals (Ry), and the two electron variances $\Delta^2 E_{ij}$ (Ry^2)

LIES Data Tape Input (cont.)

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
K(1920)		An array that contains 16 sets of subconfigurations; each set contains: the set index number, the number of electrons in a subconfiguration of the set, the total number of subconfigurations in the set, the occupied shells in a subconfiguration, and the subconfigurations

HALIDE Data Card Input

HEADER(12)		An alphanumeric array that stores 72 character "title" messages
KMAXIN		The maximum number of ions allowed in the calculations. (Example: If KMAXIN = 7, then U, U^{+}, . . . , U^{6+} are the only ions used)
KRANGE		The maximum number of ions allowed on either "side" of the principal ion. (Example: If KRANGE = 2 and the principal ion is U^{4+}, then U^{2+}, U^{3+}, U^{4+}, U^{5+}, and U^{6+} are the only ions used)
AMASS	A	The mass of uranium (235)
C1		An arbitrary multiplicative factor for the ionization lowering variable (1.06)
C2		An arbitrary multiplicative factor for the energy spread of all subconfigurations (1.0)
EPSI		Convergence criteria for $\bar{z}$ iteration (0.01)
SZERO	s_0	Cutoff parameter used in calculating plasma effects (2.0)

HALIDE Data Card Input (cont.)

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
MK(12)	$m_k = m_{K-1}$	An array containing the values, for each ion, of a parameter in the energy level distribution ($m_1 = 0.44$ [m_k, k = 2, 12 = 0])
UMAX	u_{max}	Maximum frequency allowed in the opacity calculations (If UMAX $\neq$ 0, then the input UMAX is used at all θ, Γ points. If UMAX = 0, then the OPAC routine computes a UMAX for each θ, Γ point)
EPSEND	R	Used in computing UMAX (0.05)
EPSION		Minimum fractional population an ion must have to be included in the opacity calculation (0.005)
EPSCON		Minimum value that the quantity $\Phi_k(K)/U_k^0$ must have for the sub-configuration K in the ion with net charge k to be included in the opacity calculation (0.001)
EPSCL		This parameter determines whether or not the continuous absorption becomes distributed according to Eq. (103) (0.5). If the relative change in $S_c(n\ell j, k\ell' j')$ over a cluster width is greater than EPSCL, the strength is distributed according to Eq. 103; otherwise the entire strenth is placed in the interval in which the cluster center lies
CCL		An arbitrary multiplicative factor for the cluster width (1.0)
CL		An arbitrary multiplicative factor for the number of lines (1.0)
EPSB1 EPSB2		These numbers are used to determine if a given cluster is making significant contribution to the local Planck mean opacity
EPSWK		Criteria for selecting strong clusters (0.1)

HALIDE Data Card Input (cont.)

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
BIGX		Determines the mesh for integrating transmission over mass depth
GI		Determines when the curve of growth is to be used to calculate the transmission by a cluster of lines
CGMESH		Determines, when necessary, a fine-frequency mesh for integrating the transmission over the standard interval of size Δ
EPST		Determines the largest mass depth at each frequency at which the transmission is calculated
EPSTR		When $N\bar{\tau}$ is less than EPSTR, T_j is set to unity at all frequencies
NMIN(12, 5)	$n_{min}(k, I)$	An array that contains the minimum n for each ion and each angular momentum
DEF(12, 5)	$\mu_k(I)$	An array that contains the asymptotic defect for each ion and each angular momentum

OPAC Data Card Input

OPAC does not read input data cards. HALIDE reads the cards and transfers the necessary information to OPAC.

OPAC Data Tape Input

EIG(12, 7, 7)	$\epsilon_k(i)$	An array containing L-shell eigenvalues (Ry) as a function of ion, angular momentum state, and principal quantum number
DEFI(12, 7, 7)		An array containing the required defects for each ion, each angular momentum state, and each principal quantum number

OPAC Data Tape Input (cont.)

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
DEFAS(12, 7)	$\mu_k(I)$	An array containing the asymptotic defect for each ion, and each angular momentum
FII(7, 7)		An array containing a factor in the calculation of c', Eq. (90)
IPRME(7, 3)		An array containing the allowed final angular momentum states associated with the initial angular momentum states in a transition
JMAX(7)		An array containing the maximum number of allowed final angular momentum states associated with the initial angular momentum states in a transition
LHI(7)		An array containing the maximum number of electrons allowed in M-shells (one-electron degeneracies)
LI(7)		An array relating the index I with the quantum number ℓ
LNASKI(12, 7)	$n_{as}(k, I)$	For $n \geq n_{as}(k, I)$, we find oscillator strengths by extrapolating back from the continuum
LNCKI(12, 7)	$n_c(k, I)$	If $n > n_c(k, I)$, the electron is an E-electron
LNFKI(12, 7)	$n_F(k, I)$	Shells with $n \leq n_F(k, I)$ are always filled
LNMINI(7)	$n_{min}(k, I)$	The smallest principal quantum numbers considered in the calculation of opacity
LNPEKI(12, 7)	$n'_e(k, I)$	The principal quantum number of the first (lowest n) possibly empty shell with angular momentum index I
NFKI(7)		I-shell occupation numbers

OPAC Data Tape Input (cont.)

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
SIG1(5, 20, 13)	σ_{ij}	An array containing the bound-free σ's for the first five ions: U, U^{+}, U^{2+}, U^{3+}, and U^{4+} (atomic units)
SIG2(7, 11, 13)	σ_{ij}	An array containing the bound-free σ's for the next seven ions: U^{5+}, . . . , U^{11+} (atomic units)
A1(5, 20, 12) A2(7, 11, 12)		Parameters used in interpolating bound-free σ's between free-electron kinetic energies at which they are tabulated
SIGB1(5, 20, 3)	σ^{2}_{ij}	An array containing the bound-bound σ^{2}'s for the first five ions: U, U^{+}, U^{2+}, U^{3+}, and U^{4+} (atomic units)
SIGB2(7, 11, 3)	σ^{2}_{ij}	An array containing the bound-bound σ^{2}'s for the next seven ions: U^{5+}, . . . , U^{11+} (atomic units)
SIGF1(5, 20)		An array containing the bound-free σ's for the first two ions at an energy of 1.0×10^{-3} Rydbergs and for the next three ions at an energy of 1.0×10^{-2} Rydbergs
SIGF2(7, 11)		An array containing the bound-free σ's for the next seven ions at an energy of 1.0×10^{-2} Rydbergs
AF1(5, 20) AF2(7, 11)		These arrays appear in the program but play no computational role. At first, it was intended to use them to increase the accuracy of the method we used for extrapolating back from the continuum to obtain bound-bound oscillator strengths

DESCRIPTION OF INPUT DATA CARDS

Data cards are required for all three principal routines of the program, LIES, HALIDE, and OPAC. The data cards necessary for OPAC are read by HALIDE.

LIES Data

Element Identification Card. The atomic number of uranium. The format is (I6).

Title Card. Any remarks may be punched on this card with a maximum of 72 characters. The remarks are printed at the beginning of LIES output. The format is (12A6).

Switching Card. Any negative integer; it is used to force a call to HALIDE. This is a repeat of the element identification card. The format is (I6).

HALIDE Data

Title Card. Any remarks may be punched on this card with a maximum of 72 characters. The remarks are printed at the beginning of HALIDE output. The format is (12A6)

HALIDE Parameter Card 1. This card contains the control parameters for HALIDE and the thermodynamics. In standard FORTRAN notation, the list is KMAXIN, KRANGE, AMASS, C1, C2, EPSI, SZERO, and the format is (2I10, 5E10.4).

HALIDE Parameter Cards 2. These cards contain the elements of the m_k array. In standard FORTRAN the list is (MK(I), I=1, KMAXIN), and the format is (8E10.4). Therefore, if KMAXIN is greater than eight, two cards are necessary.

OPAC Data

OPAC Parameter Cards. The next three cards are parameter cards for OPAC. In standard FORTRAN notation the list is as follows:

Card 1. UMAX, EPSEND, EPSION, EPSCON, EPSCL

Card 2. CCL, CL, EPSB1, EPSB2, EPSWK

Card 3. BIGX, GI, CGMESH, EPST, EPSTR

The format for each card is (5E10.4).

The next two types of cards are to be used in sets. There may be as many sets as desired.

Temperature Card. This card contains the following list: THETA, DELNU, NOGAMA. The parameter DELNU is the increment in frequency in the opacity calculation. It is also tested; if DELNU equals zero, the opacities for the associated temperatures are not calculated. The format is (2E10.4, I10).

GAMMA Card(s). This card(s) contains the gamma's associated with the preceding temperature. In standard FORTRAN notation, the list is (GAMMA(I), I=1, NOGAMA). The maximum number of gamma's that may be used with one emperature is twenty; therefore, more than one gamma card may be necessary for a "set." The format is (8E10.4).

Blank Card. A blank card must follow the data.

Word	NZI	
Column	1-6	
Format	I6	
Card 1		
Symbol	z	

Word	HEAD(12)	
Column	1-72	
Format	12A6	
Card 2		
Symbol		

Word	NZI	
Column	1-6	
Format	I6	
Card 3	If NZI < 0, HALIDE subroutine is called. If NZI = 0, program terminates after LIES calculation.	
Symbol	z	

Word	HEADER(12)	
Column	1-72	
Format	12A6	
Card 4		
Symbol		

Word	KMAXIN	KRANGE	AMASS	C1	C2	EPSI	SZERO
Column	1-10	11-20	21-30	31-40	41-50	51-60	61-70
Format	I10	I10	E10.4	E10.4	E10.4	E10.4	E10.4
Card 5							
Symbol			A				s_0

Word	MK(12)	
Column	1-80	
Format	8E10.4	
Card 6	If KMAXIN is > 8, more than one card must be used.	
Symbol		

Word	UMAX	EPSEND	EPSION	EPSCON	EPSCL	
Column	1-10	11-20	21-30	31-40	41-50	
Format	E10.4	E10.4	E10.4	E10.4	E10.4	
Card 7						
Symbol						

Word	CCL	CL	EPSB1	EPSB2	EPSWK	
Column	1-10	11-20	21-30	31-40	41-50	
Format	E10.4	E10.4	E10.4	E10.4	E10.4	
Card 8						
Symbol						

Word	BIGX	GI	CGMESH	EPST	EPSTR	
Column	1-10	11-20	21-30	31-40	41-50	
Format	E10.4	E10.4	E10.4	E10.4	E10.4	
Card 9						
Symbol						

Word	THETA	DELNU	NOGAMA	
Column	1-10	11-20	21-30	
Format	E10. 4	E10. 4	I10	
Card 10				
Symbol	θ	Δ		

Word	GAMA(20)	
Column	1-80	
Format	8E10. 4	
Card 11	If NOGAMA > 8, then more than one card must be used.	
Symbol	Γ	

Cards 10 and 11 may be repeated, in sets, as many times as desired.

Word	
Column	
Format	
Card 12	Blank card.
Symbol	

DEFINITION OF OUTPUT VARIABLES

The term orbital is defined as orbital plus spin orbital.

LIES Output Data

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
G(12, 2, 20)	$g_k(K)$	An array containing the degeneracies of subconfigurations
E(15, 2, 20)	$E_k(i)$ $E_k(K)$ $E_k(\{N_i\})$	An array containing the mean energy for each ion, primary and secondary set of subconfigurations, and each subconfiguration in a set (Ry)
EM(12, 2, 20)		An array containing the mean energy relative to the mean energy of the ground subconfiguration for each ion, each set of subconfigurations, primary or secondary, and each subconfiguration in a set ($EM_{ijk} = E_{ijk} - E_{ijk_{min}}$) (Ry)
DELE2(12, 2, 20)	$\Delta^2 E_k(K)$ $\Delta^2 E_k(\{N_i\})$	An array containing the dispersion in energy of a subconfiguration for each ion, each set of subconfigurations, primary or secondary, and each subconfiguration in a set (Ry^2)
EPS(12, 2, 20, 6)		An array containing the eigenvalue associated with each occupied orbital for each ion, each set of subconfigurations, primary or secondary, each subconfiguration in a set, and each orbital (Ry)

HALIDE Output Data

KD	KD = integer $[\bar{z} + 0.5]$.
KMIN	An index that represents the ion with least charge used in the calculation [KMIN = MAX(KD - KRANGE, 1)]

HALIDE Output Data (cont.)

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
KMAX		An index that represents the ion with greatest charge used in the calculations [KMAX = MIN(KD + KRANGE, KMAXIN)]
THETA	θ	Temperature in electron volts
T1	R	Temperature in degrees Rankin
T2	K	Temperature in degrees Kelvin
GAMMA	Γ	Current Γ associated with temperature (GAMMA = GAMA(I), where I is the current index)
PK(12)	P_{k-1}	An array containing the population for each ion as a function of θ, Γ
UK(12)	U_{k-1}	An array containing the partition function for each ion as a function of θ, Γ
D1UK(12)	$U_{k-1, \beta}$	An array containing the first derivatives of the partition function for each ion
D2UK(12)	$U_{k-1, \beta\beta}$	An array containing the second derivatives of the partition function for each ion
UK1(12)	U^0_{k-1}	
D1UK1(12)	$U^0_{k-u\beta}$	
D2UK1(12)	$U^0_{k-1, \beta\beta}$	
EX(15)	$U^E_{k-1} \exp(-I_{k-1/\theta})$	
EX1(15)	$\left[U^E_{k-1} \exp(-I_{k-1/\theta})\right]_{\beta\beta}$	
EX2(15)	$\left[U^E_{k-1} \exp(-I_{k-1/\theta})\right]_{\beta\beta}$	

HALIDE Output Data (cont.)

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
UK2	$U^1_{k_{max}}$	
D1UK2	$U^1_{k_{max}}, \beta$	
D2UK2	$U^1_{k_{max}}, \beta\beta$	
ZBAR	$\bar{z}$	The average number of free electrons per nucleus
ZBACK1		The value of ZBAR computed on the next to last iteration
ZBACK2		The value of ZBAR computed on the second to last iteration
ZSTAR	z^*	
AJAY	$\bar{J}$	
TEMP	$\bar{J}\vartheta/\bar{z}$	
ITER		The number of iterations for ZBAR
EKE	E_{kin}	The free translational contribution to the total internal energy (erg/gm)
EPL	E_p	The plasma contribution to the total internal energy (erg/gm)
EIN	E_{ex}	The exitation contribution to the total internal energy (erg/gm)
EION	E_{ion}	The ionization contribution to the total internal energy (erg/gm)
PKE	P_{kin}	The kinetic contribution to the total pressure (dyne/cm^2)
PPL	P_p	The plasma contribution to the total pressure (dyne/cm^2)
UK1(KMAX+1)	$U^0_{k_{max}}$	UK1(KMAX + 1) is set equal to zero if KMAX is equal to 12

HALIDE Output Data (cont.)

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
D1UK1(KMAX+1)	$U^0_{k_{max}}, \beta$	
D2UK1(KMAX+1)	$U^0_{k_{max}}, \beta\beta$	
RHO	ρ	The density in g/cm^3
TAU	τ or v	The specific volume in cm^3/g
PRESHR	P	The total pressure in $dynes/cm^2$
ENERGY	E	The total internal energy in ergs/g
CV	C_v	The specific heat at constant volume in ergs/g/eV
DEDTAU	E_v	The derivative of internal energy with respect to volume in $ergs/cm^3$
CP	C_p	The specific heat at constant pressure in ergs/g/eV
ENTHLP	W	The enthalpy in ergs/g
SS	S	The entropy in ergs/g/eV
R1		The density in lb/ft^3
TAU1		The specific volume in ft^3/lb
P1		The total pressure in atmospheres
E1		The total internal energy in Btu/lb
CV1		The specific heat at constant volume in Btu/lb/R
D1		The derivative of internal energy with respect to volume in Btu/ft^3
CP1		The specific heat at constant pressure in Btu/lb/R
EN1		The enthalpy in Btu/lb
ET1		The entropy in Btu/lb/R
E2		The total internal energy in cal/g
CV2		The specific heat at constant volume in cal/g/K

HALIDE Output Data (cont.)

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
D2		The derivative of internal energy with respect to volume in cal/cm^3
CP2		The specific heat at constant pressure in cal/g/K
EN2		The enthalpy in cal/g
ET2		The entropy in cal/g/K

OPAC Output Data

UMAX		The maximum u used in the calculation; $u = h\nu/\theta$
DELNU	Δ	The mesh size in u space used in the calculation
MMAX		MMAX = integer [UMAX/DELNU]
APC(300)		An array whose elements are proportional to the continuous opacity except at the time of output in which case APC(M) = M * Δ, where M = 1, . . . , MMAX.
CONT(300)	$\kappa_c(u)$	An array containing continuous local Planck mean opacities
PLOCAL(300)	$\kappa_p(u)$	An array containing the total local Planck mean opacities (cm^2/gm)
AROS(300)	$\kappa_R(u)$	An array containing the total local Rosseland mean opacities (cm^2/gm)
PKAP1	$\overline{\kappa}_{p_c}$	The overall Planck continuous opacity (cm^2/gm)
PKAP2	$\overline{\kappa}_p$	The overall Planck mean opacity (cm^2/gm)
RKAP1	$\overline{\kappa}_{R_c}$	The overall Rosseland continuous opacity (cm^2/gm)
RKAP2	$\overline{\kappa}_R$	The overall Rosseland mean opacity (cm^2/gm)

OPAC Output Data (cont.)

VARIABLE (FORTRAN IV)	SYMBOL	COMMENTS
ERKROS		A conservative estimate of the contribution to the Rosseland mean opacity from frequencies greater than UMAX
TIMEC		The time in seconds per transition used to calculate the opacity
MAXPTS		The total number of transitions involved in calculating the opacity for this θ, Γ point
MAXPTD		The number of unmerged clusters that were stored for later calculations
NWKPTS		The number of weak clusters in the stored group of transitions; these are not involved in calculating the transmissions
NTOT		The number of strong clusters in the stored group of transitions; these are used to calculate transmissions (MAXPTD = NWKPTS + NTOT)

```
GI FOR LIES/A
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
      COMMON//
     2 DEF(12,5)      , DELE2(12,2,20), D1UK(12)       , D1UK1(12)      ,
     3 D2UK(12)       , D2UK1(12)     , EM(12,2,20)    , EPS(12,2,20,6),
     4 FMNK(12,10)    , G(12,2,20)    , GKMI(12,5,10)  , JMIN(12,2)     ,
     5 NI(12,20,6)    , NMIN(12,5)    , NSET(12,2)     , PHIK(12)       ,
     6 PK(12)         , PKI(12,20)    , POTENT(12)     , UK(12)         ,
     7 UK1(12)        , V(12)         , WKI(12,2,20)
      COMMON//
     2 AJAY  , AMASS , BETA  , BETA2 , BIGX  , CCL   , CGMESH, CHI   ,
     3 CL    , CONST1, CP    , CV    , DEDTAU, DELNU , D1EXUK, D2EXUK,
     4 D1UK2 , D2UK2 , ENERGY, ENTHLP, EPSB1 , EPSB2 , EPSCL , EPSCON,
     5 EPSEND, EPSION, EPST  , EPSTR , EPSWK , EXUK  , GAMMA , GAMMA2,
     6 GI    , KD    , KMAXIN, KMAX  , KMIN  , LASTIT, LNAMAS, LNGAMA,
     7 NP    , PRESHR, RHO   , SMLS  , SS    , SZERO , TAU   , TEMP  ,
     8 THETA , THETAR, THETA2, THETA3, UK2   , UMAX  , ZBAR  , ZSTAR
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C
C        LIES CALCULATES
C                  MEAN CONFIGURATION ENERGIES,
C                  DISPERSION IN ENERGY OF A CONFIGURATION,
C                  EIGENVALUE ASSOCIATED WITH EACH OCCUPIED ORBITAL
C
      COMMON/GALB/ EN(1200),K(1920)
      DIMENSION HEAD(12),MORB(6),KZC(15,3),NLOC(6),AN(6),
     2          E(15,2,20),NZRO(6),EPSZRO(6),FZRO(5),Q(6,6),SIG(6,6)
      REAL LNAMAS,LNGAMA
C
C        INPUT TAPE UNIT
C
      NT=       11
  100 READ(5,701) NZI
      IF(NZI.LT.0) CALL HALIDE
      IF(NZI.EQ.0) CALL EXIT
      READ(5,700)(HEAD(J),J=1,12)
      WRITE(6,750)
      READ(NT) NZT,NP,NUMZCS
      READ(NT) (MORB(J),J=1,NP)
      READ(NT) (KZC(J,1),KZC(J,2),KZC(J,3),J=1,NUMZCS)
      READ(NT) (EN(J),J=1,1200)
      READ(NT) (K(J),J=1,1920)
      WRITE(6,700)(HEAD(J),J=1,12)
      WRITE(6,751) NZT,NP,NUMZCS
      WRITE(6,752)EN
      WRITE(6,750)
      WRITE(6,753)K
      NZC=      1
      NK=       2
C
C
  110 IF(NZC.GT.NUMZCS) GO TO 100
      DO 120 I=1,12
      II=       I
      L1=       100*(II-1)+2
      IF(KZC(NZC,1).EQ.INT(EN(L1)+.5)) GO TO 130
  120 CONTINUE
```

```
      CALL ERROR(1,0120)
  130 IF(NZI.EQ.INT(EN(L1-1) +.5)) GO TO 140
      CALL ERROR(1,0130)
  140 POTENT(NZC)=EN(L1+1)
      KION=     EN(L1) +.5
      DO 160 I2=1,NP
      L2=       L1+1+I2
      NZRO(I2)= EN(L2)
      L3=       L2+NP
      EPSZRO(I2)= EN(L3)
      L4=       L3+NP
      FZRO(I2)= EN(L4)
      L5=       L1+1+2*NP + I2*NP
      L6=       L5 +NP*NP
      DO 150 I3=1,NP
      L7=       L5+I3
      Q(I2,I3)= EN(L7)
      L8=       L6+I3
  150 SIG(I2,I3)=EN(L8)
  160 CONTINUE
      F2=       0.
  170 DO 180 J=1,16
      J1=       J
      M1=       120*(J1 - 1) + 1
      IF(KZC(NZC,NF).EQ.K(M1)) GO TO 190
  180 CONTINUE
      CALL ERROR(1,0180)
  190 J2=       M1 + 2
      NLECT=    K(J2 - 1)
      NXK=      NK-1
      NSET(NZC,NXK)= K(J2)
      NN=       NSET(NZC,NXK)
      DO 200 J=1,NP
      J3=       J2 + J
  200 NLOC(J)=  K(J3)
      KOUNT=    1
      F1=       0.
      NXZC=     KZC(NZC,1)
      NXK=      NK - 1
  210 IF(KOUNT.GT.NN  ) GO TO 405
      M2=       M1 + 8+ (KOUNT - 1)*NP
      F3=       0.
      ATOT=     0.
      DO 220 J=1,NP
      J5=       M2 + J
      AN(J)=    K(J5)
      IF(NK.EQ.2) NI(KION,KOUNT,J)= K(J5)
  220 ATOT=     ATOT + AN(J)
      IF(NLECT.EQ.INT(ATOT + .5)) GO TO 230
      F3=       1.
      WRITE(6,756) KZC(NZC,NK),KOUNT
C
C
  230 SUM1=     0.
      SUM2=     0.
      SUM4=     0.
      DO 250 K1=1,NP
```

```
      SUM1=      SUM1 + AN(K1)*FZRO(K1)
      SUM2=      SUM2 + AN(K1)*(AN(K1) - 1.)/2.*Q(K1,K1)
      IF(K1.EQ.NP) GO TO 250
      SUM3=      0.
      K2=        K1 + 1
      DO 240 K3=K2,NP
  240 SUM3=      SUM3 + AN(K3)*Q(K1,K3)
      SUM4=      SUM4 + AN(K1)*SUM3
  250 CONTINUE
      E(NXZC,NXK,KOUNT)=  SUM1 + SUM2 + SUM4
C
C
      DELE2(NZC,NXK,KOUNT)= 0.
      SUMI1=     0.
      SUMI2=     0.
      DO 256 K1=1,NP
      TEMPM1=    MORB(K1)
      TEMP1=     AN(K1)*(AN(K1)-1.)*(TEMPM1-AN(K1))*(TEMPM1-AN(K1)-1.)
     2            *SIG(K1,K1)
      TEMP2=     (TEMPM1-2.)*(TEMPM1-3.)
      IF(TEMP1.EQ.0..OR.TEMP2.EQ.0.) GO TO 252
      SUMI1=     SUMI1+ TEMP1/TEMP2
  252 IF(K1.EQ.NP) GO TO 256
      TEMP3=     AN(K1)*(TEMPM1-AN(K1))/(TEMPM1-1.)
      N=         K1+1
      SUMI3=     0.
      DO 254 K2=N,NP
      TEMPM2=    MORB(K2)
  254 SUMI3=     SUMI3+ AN(K2)*(TEMPM2-AN(K2))*SIG(K1,K2)/(TEMPM2-1.)
      SUMI2=     SUMI2+TEMP3*SUMI3
  256 CONTINUE
      DELE2(NZC,NXK,KOUNT)= .5*SUMI1+SUMI2
C
C
      DO 280 K1= 1,NP
      IF(AN(K1).NE.0.) GO TO 260
      EPS(NXZC,NXK,KOUNT,K1) = 0.
      GO TO 280
  260 SUM1=      0.
      DO 270 K2=1,NP
  270 SUM1=      SUM1+AN(K2)*Q(K1,K2)
      EPS(NXZC,NXK,KOUNT,K1)= FZRO(K1)+SUM1- Q(K1,K1)
  280 CONTINUE
C
C
      PGI=       1.
      DO 320 J1=1,NP
      NF=        AN(J1)
      MF=        MORB(J1) - NF
      IF(MF .GE. 0) GO TO 290
      F1=        KOUNT
      PGI=       0.
      GO TO 330
  290 IF(NF .NE. 0) GO TO 300
      GI=        1.
      GO TO 310
  300 GI=        FACT(MORB(J1))/(FACT(NF)*FACT(MF))
```

```
  310 PGI=       PGI*GI
  320 CONTINUE
  330 G(NXZC,NXK,KOUNT)=  PGI
      IF(KOUNT.EQ. NN) GO TO 340
      KOUNT=     KOUNT + 1
      GO TO 210
C
C          ENERGY ZERO SELECTION
C
  340 JJ=        1
      DO 370 N=1,NN
      IF(E(NXZC,NXK,JJ  ) .LT. E(NXZC,NXK,N))  GO TO 370
      JJ  =      N
      JMIN(NZC,NXK)= N
  370 CONTINUE
      NSET1=     NN    + 1
      E(NXZC,NXK,NSET1)=  E(NXZC,NXK,JJ  )
  400 CONTINUE
  405 IF(F3.EQ.0.) WRITE(6,750)
      WRITE(6,757) NZT,KZC(NZC,1),KZC(NZC,NK)
      KOUNT=         1
  410 I1=        M1 + 3 + NP + (KOUNT - 1)*NP
      IF(KOUNT .GT. NN  ) GO TO 420
      IF(INT(F1 + .5) .EQ. KOUNT) WRITE(6,759)
      I2= I1+NP-1
      EM(NXZC,NXK,KOUNT)= E(NXZC,NXK,KOUNT) -E(NXZC,NXK,NSET1)
      WRITE(6,760)(K(J),J=I1,I2),G(NXZC,NXK,KOUNT),E(NXZC,NXK,KOUNT),
     2 EM(NXZC,NXK,KOUNT),E(NXZC,NXK,NSET1),DELE2(NZC,NXK,KOUNT)
  417 WRITE(6,761)(EPS(NXZC,NXK,KOUNT,J),J=1,NP)
      KOUNT=     KOUNT + 1
      GO TO 410
  420 IF(NK.EQ.3) GO TO 430
      NK=        3
      IF(KZC(NZC,NK) .EQ. 0) GO TO 430
      GO TO 170
  430 NZC=       NZC + 1
      NK=        2
      GO TO 110
C
C         INPUT FORMATS
C
  700 FORMAT(12A6)
  701 FORMAT(I6)
C
C          OUTPUT FORMATS
C
  750 FORMAT(1H1)
  751 FORMAT(1H0,6HATOMIC,8X,9HNUMBER OF,9X,9HNUMBER OF,/7H NUMBER,5X,15
     2HACTIVE ORBITALS,5X,11HOUTER CORES,/4X,I4,10X,I3,16X,I3/)
  752 FORMAT(19H EN ARRAY CONTAINS ,/(10(1X,1PE10.4)))
  753 FORMAT(18H K ARRAY CONTAINS ,/(20(1X,I3)))
  755 FORMAT(29H1 ZCORE  1ST OUTER  2ND OUTER,/12X,4HCORE,7X,4HCORE,/3X,
     2I3,7X,I3,7X,I3)
  756 FORMAT(36H1 CAUTION- NUMBER OF ELECTRONS IN K=,I3, 5H,SET ,I2,32H
     2DOES NOT EQUAL REQUIRED NUMBER.)
  757 FORMAT(1H0,3X,1HZ,4X,2HZC,5X,1HK,/1X,I4,4X,I2,4X,I2)
  759 FORMAT(46H0 G FUNCTION IS DEFINED AS ZERO, WHEN I .GT. M1)
  760 FORMAT(18H0N1 N2 N3 N4 N5 N6,15X,1HG,15X,1HE,10X,6HE-EMIN,12X,4HEM
     2IN,9X,7H    D2E,//6(1X,I2),5(2X,1PE14.8))
  761 FORMAT(1H0,14X,3HEPS,6(2X,1PE14.8))
      END
```

```
@I FOR FACT/A
      FUNCTION FACT(M)
C        GIVEN M, CALCULATES M FACTORAL
      FACT=     1.
      DO 1 I=1,M
      A=        I
      FACT=     FACT*A
    1 CONTINUE
      RETURN
      END
```

```
@I FOR HALIDE/A
      SUBROUTINE HALIDE
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
      COMMON//
     2 DEF(12,5)      , DELE2(12,2,20), D1UK(12)       , D1UK1(12)      ,
     3 D2UK(12)       , D2UK1(12)     , EM(12,2,20)    , EPS(12,2,20,6),
     4 FMNK(12,10)    , G(12,2,20)    , GKMI(12,5,10)  , JMIN(12,2)     ,
     5 NI(12,20,6)    , NMIN(12,5)    , NSET(12,2)     , PHIK(12)       ,
     6 PK(12)         , PKI(12,20)    , POTENT(12)     , UK(12)         ,
     7 UK1(12)        , V(12)         , WKI(12,2,20)
      COMMON//
     2 AJAY  , AMASS , BETA  , BETA2 , BIGX  , CCL   , CGMESH, CHI   ,
     3 CL    , CONST1, CP    , CV    , DEDTAU, DELNU , D1EXUK, D2EXUK,
     4 D1UK2 , D2UK2 , ENERGY, ENTHLP, EPSB1 , EPSB2 , EPSCL , EPSCON,
     5 EPSEND, EPSION, EPST  , EPSTR , EPSWK , EXUK  , GAMMA , GAMMA2,
     6 GI    , KD    , KMAXIN, KMAX  , KMIN  , LASTIT, LNAMAS, LNGAMA,
     7 NP    , PRESHR, RHO   , SMLS  , SS    , SZERO , TAU   , TEMP  ,
     8 THETA , THETAR, THETA2, THETA3, UK2   , UMAX  , ZBAR  , ZSTAR
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
      COMMON/GAL/EX(15),EX1(15),EX2(15)
      COMMON/GALA/EKE,EPL,EIN,EI,PKE,PPL
      DIMENSION HEADER(12),GAMA(20),MK(12),POT(12),PKB1(12),PKB2(12)
      DATA PKB1/12*0./
      DATA PKB2/12*0./
      REAL LNAMAS,LNGAMA,MK,MK2
C
C          INPUT TAPE UNIT
C
      NT=       11
      READ(5,900)(HEADER(I),I=1,12)
      READ(5,901) KMAXIN,KRANGE,AMASS,C1,C2,EPSI,SZERO
      READ(5,902) (MK(I),I=1,KMAXIN)
      READ(5,906) UMAX,EPSEND,EPSION,EPSCON,EPSCL
      READ(5,906) CCL,CL,EPSB1,EPSB2,EPSWK
      READ(5,906) BIGX,GI,CGMESH,EPST,EPSTR
      READ(NT)     ((NMIN(I,J),J=1,5),I=1,12)
      READ(NT)     (( DEF(I,J),J=1,5),I=1,12)
      WRITE(6,950)
      WRITE(6,900)(HEADER(I),I=1,12)
      WRITE(6,903) KMAXIN,KRANGE,AMASS,C1,C2,SZERO,EPSI
      WRITE(6,909) (MK(I),I=1,KMAXIN)
      WRITE(6,904) UMAX,EPSEND,EPSION,EPSCON,EPSCL
      WRITE(6,907) CCL,CL,EPSB1,EPSB2,EPSWK
      WRITE(6,908) BIGX,GI,CGMESH,EPST,EPSTR
      CONST1=   9.65247E11/AMASS
      DO 80 I1=1,KMAXIN
   80 MK(I1)=        (MK(I1) + 1)
      V(1)=     0.
      DO 90 I1=2,KMAXIN
   90 V(I1)=    V(I1-1) +POTENT(I1-1)
      LNAMAS=   ALOG(AMASS)
  100 IG=       0
C
C
      READ(5,905) THETA,DELNU,NOGAMA
      IF(THETA.LE.0.) CALL EXIT
      THETA2=   THETA**1.5
```

```
      THETA3=    SQRT(THETA2)
      THETAR=    13.595/THETA
      BETA=      1./THETA
      BETA2=     BETA*BETA
      READ(5,902) (GAMA(I),I=1,NOGAMA)
C
C
  101 IG=        IG + 1
      IF (IG .GT. NOGAMA) GO TO 100
      GAMMA=     GAMA(IG)
      GAMMA2=    SQRT(GAMMA)
      LNGAMA=    ALOG(GAMMA)
      J=         JMIN(1,1)
        PK(1)=   G(1,1,J)
      ZOH=       PK(1)
      DO 120 I1=2,KMAXIN
      J=         JMIN(I1,1)
      KION=      I1 - 1
      AK=        KION
        PK(I1)= 0.
      DO 110 I2=1,KION
  110   PK(I1)=  PK(I1) + POTENT(I2)
        PK(I1)=   PK(I1)/THETA
      PK(I1)=    AK*LNGAMA -PK(I1)
        PK(I1)= G(I1,1,J)*EXP(  PK(I1))
  120 ZOH=       ZOH +   PK(I1)
      DO 130 I1=1,KMAXIN
  130   PK(I1)=   PK(I1)/ZOH
      ITER=      0
      LASTIT=     0
      ZBACK1=    0.
      ZBACK2=    0.
      KMIN=      1
      KMAX=      KMAXIN
C
C
  140 ZBAR=      0.
      ZSTAR=     0.
      DO 150 I1=KMIN,KMAX
      KION=      I1 - 1
      AK=        KION
      ZBAR=      ZBAR +AK*PK(I1)
  150 ZSTAR=     ZSTAR +AK*AK*PK(I1)
      ZSTAR=     ZSTAR/ZBAR
      SMLS=      ZBAR*(1. +ZSTAR)
      IF(SMLS.LT.SZERO) GO TO 155
      CHI=       (1. + (45.153*ZBAR*(1. + ZSTAR)**1.5)/
     2             (THETA3*GAMMA2))**.33333333 - 1.
      AJAY=      C1*(CHI +CHI*CHI/2.)/(1.+ZSTAR)
      GO TO 156
  155 CONTINUE
      CHI=       (1. +(45.153*SZERO*(1. +ZSTAR)**.5)/(THETA3*GAMMA2))
     2            **.33333333 -1.
      AJAY=      C1*(CHI +CHI*CHI/2.)*ZBAR/SZERO
  156 CONTINUE
      TEMP=      AJAY*THETA/ZBAR
      DO 160 I1=1,KMAXIN
```

```
      AJ=         I1
  160 POT(I1)=    POTENT(I1) - AJ*TEMP
      PHIK(1)=    0.
      DO 180 I1=2,KMAXIN
      PHIK(I1)= 0.
      DO 170 I2=2,I1
  170 PHIK(I1)= PHIK(I1) +POT(I2-1)
      PHIK(I1)= PHIK(I1)/THETA
  180 CONTINUE
      KD=         INT(ZBAR + .5)
      KMIN=       MAX0(KD - KRANGE,1)
      KMAX=       MIN0(KD+ KRANGE,KMAXIN)
C
C
      IF (LASTIT .EQ. 2) GO TO 500
      IF (ITER .NE. 0) GO TO 400
C
  190 CONTINUE
      IF (IG .EQ. 1 .AND. ITER .EQ. 0) GO TO 200
      IF (KMIN .LT. KMIN1) GO TO 210
      IF (KMAX .GT. KMAX1) GO TO 220
      KMIN1=      KMIN
      KMAX1=      KMAX
      KMN=        KMIN
      KMX=        KMAX
      GO TO 450
C
  200 KMN=        KMIN
      KMX=        KMAX
  205 KMIN1=      KMIN
      KMAX1=      KMAX
      GO TO 300
  210 KMN=        KMIN
      KMX=        MIN0(KMIN1 - 1,KMAX)
      GO TO 205
  220 KMN=        MAX0(KMIN,KMAX1+1)
      KMX=        KMAX
      GO TO 205
  300 KION=       KMN
  305 AMK=        MK(KION)
      MK2=        SQRT(AMK)
      IDO=        1
C
      UK1(KION)=0.
      D1UK1(KION)=0.
      D2UK1(KION)=0.
      IF(KION.LT.KMAXIN) GO TO 306
      UK2=        0.
      D1UK2=      0.
      D2UK2=      0.
  306 TEST=       FLOAT(KION)*TEMP/13.595
  307 ICON=       1
      JI=         JMIN(KION,IDO)
      DEL=        C2*SQRT(DELE2(KION,IDO,JI))
  310 DELKI=      C2*SQRT(DELE2(KION,IDO,ICON))
      HKI=        1. + THETAR*DELKI/MK2
      EKI=        13.595*(EM(KION,IDO,ICON) -MK2*(DELKI -DEL))
```

```
      WKI(KION,IDO,ICON)=
     2          G(KION,IDO,ICON)*(HKI**(-MK(KION)))*EXP(-EKI/THETA)
      SUKI=     - EKI - MK2*DELKI*13.595/HKI
      VKI=      (SUKI**2) + (HKI**(-2))*(DELKI**2)*184.824
      J=        1
  315 IF (J .GT. NP) GO TO 320
      EPSJ=     EPS(KION,IDO,ICON,J)
      IF(EPSJ) 317,319,325
  317 IF(ABS(EPSJ).LE.TEST) GO TO 325
  319 J=        J+1
      GO TO 315
  320 IF (IDO .EQ. 2) GO TO 322
      UK1(KION)= UK1(KION) + WKI(KION,IDO,ICON)
      D1UK1(KION)= D1UK1(KION) + WKI(KION,IDO,ICON)*SUKI
      D2UK1(KION)= D2UK1(KION) + WKI(KION,IDO,ICON)*VKI
      GO TO 325
  322 UK2=      UK2 +WKI(KION,IDO,ICON)
      D1UK2=    D1UK2 + WKI(KION,IDO,ICON)*SUKI
      D2UK2=    D2UK2 + WKI(KION,IDO,ICON)*VKI
  325 IF(ICON.GE.NSET(KION,IDO)) GO TO 330
      ICON=     ICON + 1
      GO TO 310
  330 IF (IDO .EQ. 2) GO TO 450
      M=        5
      AM=       M
      ANK2=     THETAR*FLOAT((KION  )**2)
      ANK=      SQRT(ANK2)
  335 FMNK(KION,M)= (2.*AM*AM-32.)*EXP(ANK2/(AM*AM)-POTENT(KION)/THETA)
      IF (M .EQ. 10) GO TO 340
      M=        M + 1
      AM=       M
      GO TO 335
  340 I=        1
  345 M=        NMIN(KION,I)
      AM=       M
  350 GKMI(KION,I,M)= EXP(ANK2/(AM-DEF(KION,I))**2 -POTENT(KION)/THETA)
      IF(M .GE. 10) GO TO 355
      M=        M + 1
      AM=       M
      GO TO 350
  355 IF (I .GE. 5) GO TO 360
      I=        I + 1
      GO TO 345
  360 IF((KION.GE.KMAXIN).AND.(IDO.EQ.1)) GO TO 365
      KION=     KION +
      IF(KION.GT.(KMX+1).OR.KION.GT.KMAXIN) GO TO 450
      GO TO 305
  365 IDO=      2
      GO TO 307
C
C     CONVERGENCE CHECK
C
  400 IF ((ABS(1. - ZBACK1/ZBAR) - EPSI) .LE. 0.) GO TO 430
      IF (LASTIT .EQ. 0) GO TO 410
      LASTIT=   0
  410 IF (ITER .GE. 10) GO TO 420
      GO TO 190
```

```
  420 LASTIT=   2
      GO TO 450
  430 LASTIT=   LASTIT + 1
      IF (LASTIT .GE. 2) GO TO 500
  450 CALL POPART
      ITER=     ITER + 1
      ZBACK2=   ZBACK1
      ZBACK1=   ZBAR
      DO 455 I=1,15
      PKB2(I)=  PKB1(I)
  455 PKB1(I)=  PK(I)
      GO TO 140
  500 WRITE(6,950)
      CALL THERML
C
C         CONVERSION TO THE ENGLISH UNITS AND THOSE OTHER UNITS
C
      T1=       2.08574E4*THETA
      T2=       1.16052E4*THETA
      R1=       62.43*RHO
      TAU1=     1./R1
      P1=       9.86923E-7*PRESHR
      E1=       4.30211E-6*ENERGY
      E2=       2.39006E-6*ENERGY
      CV1=      2.06263E-12*CV
      CV2=      2.05947E-12*CV
      D1=       2.68571E-5*DEDTAU
      D2=       2.39006E-6*DEDTAU
      CP1=      2.06263E-12*CP
      CP2=      2.05947E-12*CP
      EN1=      4.30211E-6*ENTHLP
      EN2=      2.39006E-6*ENTHLP
      ET1=      2.06263E-12*SS
      ET2=      2.05947E-12*SS
      WRITE(6,951) THETA,T1,T2
      WRITE(6,952) GAMMA
      WRITE(6,953)
      WRITE(6,954) (I,PK(I),UK(I),D1UK(I),D2UK(I),UK1(I),D1UK1(I),
     2  D2UK1(I),EX(I),EX1(I),EX2(I),I=KMIN,KMAX)
      WRITE(6,955) ZBAR,ZBACK1,ZBACK2,UK2,D1UK2,D2UK2,ZSTAR,AJAY,TEMP,
     2  ITER
      IF(KMAXIN.EQ.12) GO TO 505
      WRITE(6,955) EKE,EPL,EIN,EI,PKE,PPL,UK1(KMAX+1),D1UK1(KMAX+1),
     2   D2UK1(KMAX+1),KD
      GO TO 510
  505 X=        0.
      WRITE(6,955) EKE,EPL,EIN,EI,PKE,PPL,X,X,X,KD
  510 CONTINUE
      WRITE(6,956)
      WRITE(6,957) RHO,TAU,PRESHR,ENERGY,ZBAR,R1,TAU1,P1,E1,ZBAR,RHO,
     2   TAU,P1,E2,ZBAR
      WRITE(6,958)
      WRITE(6,959) CV,DEDTAU,CP,ENTHLP,SS,CV1,D1,CP1,EN1,ET1,CV2,D2,
     2   CP2,EN2,ET2
      IF(DELNU.LE.0.) GO TO 101
      WRITE(6,950)
      WRITE(6,951) THETA,T1,T2
```

```
      WRITE(6,952) GAMMA
      WRITE(6,960) PRESHR,P1
      WRITE(6,961) RHO,R1
      WRITE(6,962) ZBAR
      CALL OPAC
      GO TO 101
C
C          INPUT FORMATS
C
  900 FORMAT(12A6)
  901 FORMAT(2I10,5E10.4)
  902 FORMAT(8E10.4)
  905 FORMAT(2E10.4,I10)
  906 FORMAT(6E10.4)
C
C          OUTPUT FORMATS
C
  903 FORMAT(16H0 KMAXIN  KRANGE,10X,5HAMASS,13X,2HC1,13X,2HC2,10X,5HSZE
     2RO,11X,4HEPSI,/5X,13,5X,13,5(5X,1PE10.4))
  904 FORMAT(1H0,11X,4HDMAX,9X,6HEPSEND,9X,6HEPSION,9X,6HEPSCON,10X,5HEP
     2SCL,/6X,5(1PE10.4,5X))
  907 FORMAT(1H0,12X,3HCCL,13X,2HCL,10X,5HEPSJ1,10X,5HEPSJ2,10X,5HEPSWK,
     2/6X,5(1PE10.4,5X))
  908 FORMAT(1H0,11X,4HDIGX,13X,2HGI,9X,6HCGMESH,11X,4HEPST,10X,5HEPSTR,
     2/6X,5(1PE10.4,5X))
  909 FORMAT(1H0,7X,8HMK ARRAY,/6X,6(1PE10.4,5X) ,/6X,6(1PE10.4,5X))
  950 FORMAT(1H1)
  951 FORMAT(7H0THETA=,1PE10.4,5H EV =,1PE10.4,8H DEG R =,1PE10.4,
     26H DEG K)
  952 FORMAT(7H0GAMMA=,1PE10.4)
  953 FORMAT(4H0  I,6X,6HPOP(I),5X,7HPART(I),3X,9HD1PART(I),3X,9HD2PART(
     2I),6X,6HUK0(I),4X,8HD1UK0(I),4X,8HD2UK0(I),5X,7HEXUK(I),3X,
     39HD1EXUK(I),3X,9HD2EXUK(I))
  954 FORMAT((2X,I2,10(2X,1PE10.4)))
  955 FORMAT(1H0,3X, 9(2X,1PE10.4),10X,I2)
  956 FORMAT(1H0,16X,3HRHO,21X,3HTAU,16X,8HPRESSURE,18X,6HENERGY,20X,
     24HZBAR)
  957 FORMAT(6X,1PE14.8,10H(G/CM3)    ,1PE14.8,10H(CM3/G)    ,1PE14.8,10H(
     2DYNE/CM2),1PE14.8,10H(ERG/G)    ,1PE14.8,/6X,1PE14.8,10H(LB/FT3)   ,
     31PE14.8,10H(FT3/LB)   ,1PE14.8,10H(ATM)      ,1PE14.8,10H(BTU/LB)   ,
     41PE14.8,/6X,1PE14.8,10H(G/CM3)    ,1PE14.8,10H(CM3/G)    ,1PE14.8,10
     5H(ATM)      ,1PE14.8,10H(CAL/G)    ,1PE14.8)
  958 FORMAT(1H0,17X,2HCV,18X,6HDEDTAU,22X,2HCP,16X,8HENTHALPY,17X,
     27HENTROPY)
  959 FORMAT(6X,1PE14.8,10H(ERG/G/EV),1PE14.8,10H(ERG/CM3) ,1PE14.8,10H(
     2ERG/G/EV),1PE14.8,10H(ERG/G)    ,1PE14.8,10H(ERG/EV/G),/6X,1PE14.8,
     310H(BTU/LB/R),1PE14.8,10H(BTU/FT3) ,1PE14.8,10H(BTU/LB/R),1PE14.8,
     410H(BTU/LB)   ,1PE14.8,10H(BTU/R/LB),/6X,1PE14.8,10H(CAL/G/K) ,1PE1
     54.8,10H(CAL/CM3) ,1PE14.8,10H(CAL/G/K) ,1PE14.8,10H(CAL/G)    ,1PE1
     64.8,10H(CAL/K/G) )
  960 FORMAT(11H0PRESSURE= ,1PE10.4,14H (DYNE/CM2) = ,1PE10.4,6H (ATM))
  961 FORMAT(6H0RHO= ,1PE10.4,11H (G/CM3) = ,1PE10.4,9H (LB/FT3))
  962 FORMAT(7H0ZBAR= ,1PE10.4)
      END
```

```
@I FOR POPART/A
      SUBROUTINE POPART
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
      COMMON//
     2 DEF(12,5)      , DELE2(12,2,20), D1UK(12)       , D1UK1(12)     ,
     3 D2UK(12)       , D2UK1(12)     , EM(12,2,20)    , EPS(12,2,20,6),
     4 FMNK(12,10)    , G(12,2,20)    , GKMI(12,5,10)  , JMIN(12,2)    ,
     5 NI(12,20,6)    , NMIN(12,5)    , NSET(12,2)     , PHIK(12)      ,
     6 PK(12)         , PKI(12,20)    , POTENT(12)     , UK(12)        ,
     7 UK1(12)        , V(12)         , WKI(12,2,20)
      COMMON//
     2 AJAY  , AMASS , BETA  , BETA2 , BIGX  , CCL   , COVESH, CHI   ,
     3 CL    , CONST1, CP    , CV    , DEDTAU, DELNU , D1EXUK, D2EXUK,
     4 D1UK2 , D2UK2 , ENERGY, ENTHLP, EPSB1 , EPSB2 , EPSCL , EPSCON,
     5 EPSEND, EPSION, EPST  , EPSTR , EPSWK , EXUK  , GAMMA , GAMMA2,
     6 GI    , KD    , KMAXIN, KMAX  , KMIN  , LASTIT, LNAMAS, LNGAMA,
     7 NP    , PRESHR, RHO   , SMLS  , SS    , SZERO , TAU   , TEMP  ,
     8 THETA , THETAR, THETA2, THETA3, UK2   , UMAX  , ZBAR  , ZSTAR
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C
C          POPART CALCULATES
C                    POPULATIONS,PARTITION FUNCTIONS
C                    AND PARTITION FUNCTION DERIVATIVES
C
      COMMON/GAL/EX(15),EX1(15),EX2(15)
      DIMENSION DI(5)
      DATA DI/ 2., 2., 4., 10., 14./
      REAL LNAMAS,LNGAMA
      H(X,Y,PI,TH)= (X-Y*Y/X)*EXP(-PI/TH)
      P(X,Y,PI,TH)= (2.*X -2./X*(Y*Y-16.))*EXP(-PI/TH)
      Q(X,Y,PI,TH)= (.66666667*(X**3) +2.*X*(Y*Y-16.))*EXP( -PI/TH)
      R(X,Y,PI,TH)=(-1./X-Y*Y/(3.*X**3))*EXP( -PI/TH)
      S(X,Y,PI,TH)= (-2./X-2./(3.*X**3)*(Y*Y -16.))*EXP( -PI/TH)
      T(X,Y,PI,TH)= (-3./(X**3) -Y*Y/(5.*X**5))*EXP( -PI/TH)
      ZEE=       0.
      KION=      KMIN
   10 IF (KION .GT. KMAX) GO TO 230
      ANK2=      KION*KION*THETAR
      ANK=       SQRT(ANK2)
      BNK2=      KION*13.595/TEMP
      BNK=       SQRT(BNK2)
      IBNK=      INT(BNK)
      IF (LASTIT .EQ. 0) GO TO 15
      TANK2=     THETA*ANK2
      TANK4=     TANK2*TANK2
   15 IF (ANK .GT. 5.) GO TO 45
      IF (IBNK .LT. 5) GO TO 40
      IF (IBNK .GT. 10) GO TO 25
      HUK=       0.
      D1HUK=     0.
      D2HUK=     0.
      DO 20 I=5,IBNK
      FTEMP=     FMNK(KION,I)
      HUK=       HUK + FTEMP
      IF (LASTIT .EQ. 0) GO TO 20
      A=         I
      D1HUK=     D1HUK + TANK2*FTEMP   /(A*A)
```

```
      D2HUK=     D2HUK +TANK4*FTEMP/(A**4)
   20 CONTINUE
      GO TO 100
   25 HUK=       0.
      D1HUK=     0.
      D2HUK=     0.
      QTEMP=     Q(BNK,ANK,POTENT(KION),THETA) -Q(10.5,ANK,POTENT(KION),T
     2HETA)
      FTEMP=     FMNK(KION,I)
      HUK=       HUK + FTEMP
      IF (LASTIT .EQ. 0) GO TO 30
      A=         I
      D1HUK=     D1HUK + TANK2*FTEMP/(A*A)
      D2HUK=     D2HUK + TANK4*FTEMP/(A**4)
   30 CONTINUE
      HUK=       HUK + QTEMP
      IF (LASTIT .EQ. 0) GO TO 35
      D1HUK=     D1HUK +TANK2*(P(BNK,ANK,POTENT(KION),THETA)
     2             -P(10.5,ANK,POTENT(KION),THETA))
      D2HUK=     D2HUK +TANK4*(S(BNK,ANK,POTENT(KION),THETA)
     2             -S(10.5,ANK,POTENT(KION),THETA))
   35 GO TO 100
   40 HUK=       0.
      D1HUK=     0.
      D2HUK=     0.
      GO TO 100
   45 IF (IBNK .LT. 5) GO TO 80
      IF (IBNK .GT. 10) GO TO 55
      HUK=       0.
      D1HUK=     0.
      D2HUK=     0.
      DO 50 I=5,IBNK
      FTEMP=     FMNK(KION,I)
      HUK=       HUK + FTEMP
      IF (LASTIT .EQ. 0) GO TO 50
      A=         I
      D1HUK=     D1HUK + TANK2*FTEMP/(A*A)
      D2HUK=     D2HUK + TANK4*FTEMP/(A**4
   50 CONTINUE
      GO TO 100
   55 IF (BNK .GE. ANK) GO TO 65
      HUK=       0.
      D1HUK=     0.
      D2HUK=     0.
      DO 60 I=5,10
      FTEMP=     FMNK(KION,I)
      HUK=       HUK + FTEMP
      IF (LASTIT .EQ. 0) GO TO 60
      A=         I
      D1HUK=     D1HUK + TANK2*FTEMP/(A*A)
      D2HUK=     D2HUK + TANK4*FTEMP/(A**4)
   60 CONTINUE
      GO TO 100
   65 HUK=       0.
      D1HUK=     0.
      D2HUK=     0.
      QTEMP=     Q(BNK,ANK,POTENT(KION),THETA) -Q(10.5,ANK,POTENT(KION),
```

```
     2 THETA)
       DO 70 I=5,10
       FTEMP=     FMNK(KION,I)
       HUK=       HUK + FTEMP
       IF (LASTIT .EQ. 0) GO TO 70
       A=         I
       D1HUK=     D1HUK + TANK2*FTEMP/(A*A)
       D2HUK=     D2HUK + TANK4*FTEMP/(A**4)
    70 CONTINUE
       HUK=       HUK + QTEMP
       IF (LASTIT .EQ. 0) GO TO 75
       D1HUK=     D1HUK +TANK2*(P(BNK,ANK,POTENT(KION),THETA)
      2             -P(10.5,ANK,POTENT(KION),THETA))
       D2HUK=     D2HUK +TANK4*(S(BNK,ANK,POTENT(KION),THETA)
      2             -S(10.5,ANK,POTENT(KION),THETA))
    75 GO TO 100
    80 HUK=       0.
       D1HUK=     0.
       D2HUK=     0.
       GO TO 100
   100 EUK=       0.
       D1EUK=     0.
       D2EUK=     0.
       ID=        1
   110 BNKI=      BNK + DEF(KION,ID)
       IBNKI=     INT(BNKI)
       CNKI=      FLOAT(NMIN(KION,ID)) - DEF(KION,ID)
       M=         NMIN(KION,ID)
       D=         DEF(KION,ID)
       N=         MIN0(IBNKI,10)
       IF(ANK.GT.CNKI) GO TO 145
       IF(BNK.LT.CNKI) GO TO 140
       IF(IBNKI.LE.10) GO TO 130
       EUKI=      0.
       D1EUKI=    0.
       D2EUKI=    0.
       HTEMP=     H(BNK,ANK,POTENT(KION),THETA) -H((10.5-D),ANK,POTENT(KIO
      2N),THETA)
       DO 120 I=M,10
       GTEMP=     GKMI(KION,ID,I)
       EUKI=      GTEMP
       IF(LASTIT.EQ.0) GO TO 120
       A=I
       D1EUKI=    D1EUKI + TANK2*GTEMP/((A-D)**2)
       D2EUKI=    D2EUKI + TANK4*GTEMP/((A-D)**4)
   120 CONTINUE
       EUKI=      EUKI +HTEMP
       IF(LASTIT .EQ. 0) GO TO 125
       D1EUKI=    D1EUKI +TANK2*(R(BNK,ANK,POTENT(KION),THETA)
      2             -R((10.5-D),ANK,POTENT(KION),THETA))
       D2EUKI=    D2EUKI +TANK4*(T(BNK,ANK,POTENT(KION),THETA)
      2             -T((10.5-D),ANK,POTENT(KION),THETA))
   125 GO TO 200
   130 EUKI=      0.
       D1EUKI=    0.
       D2EUKI=    0.
       DO 135 I=M,IBNKI
```

```
      GTEMP=     GKMI(KION,ID,I)
      EUKI=      EUKI + GTEMP
      IF (LASTIT .EQ. 0) GO TO 135
      A=         I
      D1EUKI=    D1EUKI + TANK2*GTEMP/((A - D)**2)
      D2EUKI=    D2EUKI + TANK4*GTEMP/((A - D)**4)
  135 CONTINUE
      GO TO 200
  140 EUKI=      0.
      D1EUKI=    0.
      D2EUKI=    0.
      GO TO 200
  145 IF (BNK .LT. CNKI) GO TO 180
      IF (BNK .GT. ANK) GO TO 155
      EUKI=      0.
      D1EUKI=    0.
      D2EUKI=    0.
      DO 150 I=M,N
      GTEMP=     GKMI(KION,ID,I)
      EUKI=      EUKI + GTEMP
      IF (LASTIT .EQ. 0) GO TO 150
      A=         I
      D1EUKI=    D1EUKI + TANK2*GTEMP/((A - D)**2)
      D2EUKI=    D2EUKI + TANK4*GTEMP/((A - D)**4)
  150 CONTINUE
      GO TO 200
  155 IF (IBNKI .LE. 10) GO TO 170
      EUKI=      0.
      D1EUKI=    0.
      D2EUKI=    0.
      HTEMP=     H(BNK,ANK,POTENT(KION),THETA) -H((10.5-D),ANK,POTENT(KIO
     2N),THETA)
      DO 160 I=M,10
      GTEMP=     GKMI(KION,ID,I)
      EUKI=      EUKI + GTEMP
      IF (LASTIT .EQ. 0) GO TO 160
      A=         I
      D1EUKI=    D1EUKI + TANK2*GTEMP/((A - D)**2)
      D2EUKI=    D2EUKI + TANK4*GTEMP/((A - D)**4)
  160 CONTINUE
      EUKI=      EUKI + HTEMP
      IF (LASTIT .EQ. 0) GO TO 165
      D1EUKI=    D1EUKI +TANK2*(R(BNK,ANK,POTENT(KION),THETA)
     2             -R((10.5-D),ANK,POTENT(KION),THETA))
      D2EUKI=    D2EUKI +TANK4*(T(BNK,ANK,POTENT(KION),THETA)
     2             -T((10.5-D),ANK,POTENT(KION),THETA))
  165 GO TO 200
  170 EUKI=      0.
      D1EUKI=    0.
      D2EUKI=    0.
      DO 175 I=M,IBNKI
      GTEMP=     GKMI(KION,ID,I)
      EUKI=      EUKI + GTEMP
      IF(LASTIT.EQ.0) GO TO 175
      A=         I
      D1EUKI=    D1EUKI + TANK2*GTEMP/((A-D)**2)
      D2EUKI=    D2EUKI + TANK4*GTEMP/((A-D)**4)
```

```
175 CONTINUE
    GO TO 200
180 EUKI=      0.
    D1EUKI=    0.
    D2EUKI=    0.
    GO TO 200
200 EUK=       EUK + DI(ID)*EUKI
    IF (LASTIT .EQ. 0) GO TO 205
    D1EUK=     D1EUK + DI(ID)*D1EUKI
    D2EUK=     D2EUK + DI(ID)*D2EUKI
205 ID=        ID + 1
    IF (ID .GT. 5) GO TO 210
    GO TO 110
210 EXUK=      HUK + EUK
    IF (LASTIT .EQ. 0) GO TO 215
    D1EXUK=    D1HUK + D1EUK
    D2EXUK=    D2HUK + D2EUK
    EX(KION)=  EXUK
    EX1(KION)= D1EXUK
    EX2(KION)= D2EXUK
215 PTENT=     POTENT(KION)/THETA
    IF(KION.GE.KMAXIN) GO TO 220
    UK(KION)= UK1(KION) +UK1(KION+1)*EXUK
    IF (LASTIT .EQ. 0) GO TO 225
    D1UK(KION)= D1UK1(KION) +(D1UK1(KION+1)*EXUK +UK1(KION
   2 + 1)*D1EXUK - POTENT(KION)*UK1(KION + 1)*EXUK)
    D2UK(KION)= D2UK1(KION) - POTENT(KION)*(D1UK(KION)- D1UK1(KION))
   2 +(D2UK1(KION+1)*EXUK +2.*D1UK1(KION+1)*D1EXUK +
   3 UK1(KION + 1)* D2EXUK - POTENT(KION)*(D1UK1(KION + 1)*EXUK +
   4 UK1(KION + 1)* D1EXUK))
    GO TO 225
220 UK(KION)= UK1(KION) +UK2*EXUK
    IF (LASTIT .EQ. 0) GO TO 225
    D1UK(KION)= D1UK1(KION) +(D1UK2*EXUK +UK2*D1EXUK
   2              -POTENT(KION)*UK2*EXUK)
    D2UK(KION)= D2UK1(KION) -POTENT(KION)*(D1UK(KION) -D1UK1(KION))
   2             +(D2UK2*EXUK +2.*D1UK2*D1EXUK
   3           +UK2*D2EXUK -POTENT(KION)*(D1UK2*EXUK
   4             +UK2*D1EXUK))
225 PK(KION)= UK(KION)*EXP((KION- 1)*LNGAMA - PHIK(KION))
    ZEE=       ZEE + PK(KION)
    KION=      KION + 1
    GO TO 10
230 K=         KMIN
235 IF (K .GT. KMAX) GO TO 240
    PK(K)=     PK(K)/ZEE
    K=         K + 1
    GO TO 235
240 IF (LASTIT .EQ. 0) RETURN
    K=         KMIN
245 IF (K .GT. KMAX) RETURN
    I=
250 IF (I .GT. NSET(K,1)) GO TO 255
    PKI(K,I)= PK(K)*WKI(K,1,I)/UK(K)
    I=         I + 1
    GO TO 250
255 K=         K + 1
    GO TO 245
    END
```

```
QI FOR THERML/A
      SUBROUTINE THERML
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
      COMMON//
     2 DEF(12,5)      , DELE2(12,2,20), D1UK(12)       , D1UK1(12)      ,
     3 D2UK(12)       , D2UK1(12)     , EM(12,2,20)    , EPS(12,2,20,6),
     4 FMNK(12,10)    , G(12,2,20)    , GKMI(12,5,10)  , JMIN(12,2)     ,
     5 NI(12,20,6)    , NMIN(12,5)    , NSET(12,2)     , PHIK(12)       ,
     6 PK(12)         , PKI(12,20)    , POTENT(12)     , UK(12)         ,
     7 UK1(12)        , V(12)         , WKI(12,2,20)
      COMMON//
     2 AJAY  , AMASS , BETA  , BETA2 , BIGX  , CCL   , CGMESH, CHI   ,
     3 CL    , CONST1, CP    , CV    , DEDTAU, DELNU , D1EXUK, D2EXUK,
     4 D1UK2 , D2UK2 , ENERGY, ENTHLP, EPSB1 , EPSB2 , EPSCL , EPSCON,
     5 EPSEND, EPSION, EPST  , EPSTR , EPSWK , EXUK  , GAMMA , GAMMA2,
     6 GI    , KD    , KMAXIN, KMAX  , KMIN  , LASTIT, LNAMAS, LNGAMA,
     7 NP    , PRESHR, RHO   , SMLS  , SS    , SZERO , TAU   , TEMP  ,
     8 THETA , THETAR, THETA2, THETA3, UK2   , UMAX  , ZBAR  , ZSTAR
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C
C         THERML CALCULATES
C                 THERMODYNAMIC PROPERTIES
C
      COMMON/GALA/EKE,EPL,EIN,EI,PKE,PPL
      DIMENSION EIK(15),EITHT(15),DRDTHT(15),DRDTAU(15),PKTHT(15),
     2PKTAU(15)
      REAL LNAMAS,LNGAMA
      RHO=       .010125*AMASS*THETA2/(GAMMA*ZBAR)
      TAU=       1./RHO
      CKBAR=     (15.051*ZBAR*(1. +ZSTAR)**.5)/(THETA3*GAMMA2)
C
C     ENERGY CALCULATION
C
      EKE=       1.5*CONST1*(1.+ZBAR)*THETA
      EPL=       -.5*CONST1*(1. +ZSTAR)*AJAY*THETA
      EIN=       0.
      EI=        0.
      DO 100 I1=KMIN,KMAX
      EIN=       EIN +PK(I1)*V(I1)
      EIK(I1)=   -D1UK(I1)/UK(I1)
      EI=        EI + PK(I1)*EIK(I1)
  100 CONTINUE
      EIN=       CONST1*EIN
      EI=        CONST1*EI
      ENERGY=    EKE +EIN +EI +EPL
C
C         PRESSURE CALCULATION
C
      PKE=       CONST1*RHO*(1+ZBAR)*THETA
      PPL=       RHO*EPL/3.
      PRESHR=    PKE +PPL
C
C         ENTHALPY CALCULATION
C
      ENTHLP=    ENERGY +PRESHR/RHO
C
C
      FSZRO=     11.56882 +1.5*LNAMAS +ZBAR +(ZBAR +1.)*LNGAMA+ALOG(ZBAR)
      DO 120 I1=KMIN,KMAX
      SAVE=      PK(I1)/UK(I1)
      IF(SAVE.EQ.0.) GO TO 120
      FSZRO=     FSZRO -PK(I1)*(ALOG(SAVE) +BETA*V(I1))
```

```
  120 CONTINUE
      FSZRO=     -CONST1*THETA*FSZRO
      CHI2=      CHI*CHI
      ARG1=      CHI2/3. +CHI +1.
      ARG2=      (2.*CHI +3.)/1.732051
      GCHI=      CHI +CHI2/2. -.5*ALOG(ARG1) +(ATAN(ARG2)
     2            -1.047197)/1.732051
      FSPL=      -CONST1/2.*THETA*GCHI
      FS=        FSZRO +FSPL
      SSPL=      (EPL -FSPL)/THETA
C
C          ENTROPY CALCULATION
C
      SS=        (ENERGY -FS)/THETA
C
C     DERIVATIVES
C
      DPDTHT=   -1.5*CKBAR/(ZBAR*THETA*(1.+CHI))
      DPDTAU=   -.5*CKBAR*RHO/(ZBAR*(1.+CHI))
      FF=        AJAY/ZBAR
      IF(SMLS.LT.SZERO) GO TO 130
      SMLF=      (-FF +1.5*CKBAR/(ZBAR*(1.+CHI)))/SMLS
      GO TO 135
  130 CONTINUE
      SMLF=      (-FF +1.5*CKBAR/(ZBAR*(1. +CHI)))/SZERO
  135 CONTINUE
      CKBAR1=    ZBAR
      CKBAR2=    CKBAR1*ZSTAR
      CKBAR3=    0.
      CKBAR4=    0.
      DO 140 I1=KMIN,KMAX
      AK=        I1-1
      CKBAR3=    CKBAR3 +(AK**3)*PK(I1)
      CKBAR4=    CKBAR4 +(AK**4)*PK(I1)
      DRDTHT(I1)= 1.5*AK*BETA +BETA2*(V(I1) +EIK(I1))
      DRDTAU(I1)= AK*RHO
  140 CONTINUE
      A1THT=     -1. +ZBAR -ZSTAR
      A2THT=     .5*SMLF*(CKBAR3 +CKBAR2 -ZBAR*SMLS)
      SUM1=      0.
      SUM2=      0.
      SUM3=      0.
      DO 150 I1=KMIN,KMAX
      A1=        I1-1
      PROD=      PK(I1)*DRDTHT(I1)
      SUM1=      SUM1 +PROD
      SUM2=      SUM2 +A1*PROD
      SUM3=      SUM3 +A1*(A1+1.)*PROD
  150 CONTINUE
      A3THT=     ZBAR*(SUM1 +.5*DPDTHT*(CKBAR2 +CKBAR1)) -SUM2
     2            -.5*DPDTHT*(CKBAR3 +CKBAR2)
      B1THT=     SMLS -(CKBAR3 +CKBAR2)/ZBAR
      B2THT=     -1. -.5*SMLF*SMLS*SMLS +.5*SMLF*(CKBAR4 +2.*CKBAR3
     2            +CKBAR2)
      B3THT=     SMLS*(SUM1 +.5*DPDTHT*(CKBAR2 +CKBAR1)) -SUM3
     2            -.5*DPDTHT*(CKBAR4 +2.*CKBAR3 +CKBAR2)
      ZBRTHT=    (A2THT*B3THT -A3THT*B2THT)/(A2THT*B1THT -A1THT*B2THT)
      SMLSTH=    (A3THT -A1THT*ZBRTHT)/A2THT
      DO 160 I1=KMIN,KMAX
      A1=        I1-1
      PKTHT(I1)= PK(I1)*((1.-A1/ZBAR)*ZBRTHT +DRDTHT(I1) -SUM1
     2            +.5*(SMLF*SMLSTH +DPDTHT)*(A1*A1 +A1 -CKBAR2 -CKBAR1))
```

```
  160 CONTINUE
      A1TAU=     -1. -(CKBAR2 -ZBAR*ZBAR)/ZBAR
      A2TAU=     -.5*ZBAR*SMLS*SMLF +.5*SMLF*(CKBAR3 +CKBAR2)
      A3TAU=     RHO*ZBAR*ZBAR +.5*ZBAR*SMLS*DPDTAU -.5*DPDTAU*(CKBAR3
     2            +CKBAR2) -RHO*CKBAR2
      B1TAU=     SMLS -(CKBAR3 +CKBAR2)/ZBAR
      B2TAU=     -1. -.5*SMLF*SMLS*SMLS +.5*SMLF*(CKBAR4 +2.*CKBAR3
     2            +CKBAR2)
      B3TAU=     RHO*ZBAR*SMLS+.5*DPDTAU*SMLS*SMLS -.5*DPDTAU*(CKBAR4
     2            +2.*CKBAR3 +CKBAR2) -RHO*(CKBAR3 +CKBAR2)
      ZBRTAU=    (A2TAU*B3TAU -A3TAU*B2TAU)/(A2TAU*B1TAU -A1TAU*B2TAU)
      SMLSTU=    (A3TAU -A1TAU*ZBRTAU)/A2TAU
      DO 170 I1=KMIN,KMAX
      A1=        I1-1
      PKTAU(I1)= PK(I1)*(RHO*(A1 -ZBAR) +.5*(SMLF*SMLSTU +DPDTAU)*
     2            (A1*A1 +A1 -CKBAR2 -CKBAR1 ))
  170 CONTINUE
C
C
      HOLD1=     0.
      HOLD2=     0.
      HOLD3=     0.
      HOLD4=     0.
      DO 250 I1=KMIN,KMAX
      EITHT(I1)= BETA2*(D2UK(I1)/UK(I1) -(D1UK(I1)/UK(I1))**2)
      HOLD1=     HOLD1 +PK(I1)*EITHT(I1)
      HOLD2=     HOLD2 +PKTHT(I1)*(EIK(I1) +V(I1))
      HOLD3=     HOLD3 +PKTAU(I1)*V(I1)
      HOLD4=     HOLD4 +PKTAU(I1)*EIK(I1)
  250 CONTINUE
      EPLTHT=    -CONST1/2.*THETA*(SMLS*(SMLF*SMLSTH +DPDTHT) +FF*SMLSTH)
     2            +EPL/THETA
C
C          CV CALCULATION
C
      CV=        CONST1*(1.5*(1.+ZBAR+THETA*ZBRTHT) +HOLD1 +HOLD2)+EPLTHT
      EKETAU=    1.5*CONST1*ZBRTAU*THETA
      EINTAU=    CONST1*HOLD3
      EITAU=     CONST1*HOLD4
      EPLTAU=    -.5*CONST1*THETA*(FF*SMLSTU +SMLS*(SMLF*SMLSTU +DPDTAU))
C
C          DEDTAU CALCULATION
C
      DEDTAU=    EKETAU +EINTAU +EITAU +EPLTAU
      ARG1=      CONST1*(1. +ZBAR +THETA*ZBRTHT) +EPLTHT/3.
      ARG2=      PRESHR -CONST1*THETA*ZBRTAU -EPLTAU/3.
      DTDTHT=    ARG1/ARG2
C
C          CP CALCULATION
C
      CP=        CV +DTDTHT (DEDTAU+PRESHR)
      RETURN
      END
```

```
WI FOR OPAC/A
      SUBROUTINE OPAC
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
      COMMON//
     2 DEF(12,5)      , DELE2(12,2,20), D1UK(12)       , D1UK1(12)      ,
     3 D2UK(12)       , D2UK1(12)     , EM(12,2,20)    , EPS(12,2,20,6),
     4 FMNK(12,10)    , G(12,2,20)    , GKMI(12,5,10)  , JMIN(12,2)     ,
     5 NI(12,20,6)    , NMIN(12,5)    , NSET(12,2)     , PHIK(12)       ,
     6 PK(12)         , PKI(12,20)    , POTENT(12)     , UK(12)         ,
     7 UK1(12)        , V(12)         , WKI(12,2,20)
      COMMON//
     2 AJAY  , AMASS , BETA  , BETA2 , BIGX  , CCL   , CGMESH, CHI   ,
     3 CL    , CONST1, CP    , CV    , DEDTAU, DELNU , D1EXUK, D2EXUK,
     4 D1UK2 , D2UK2 , ENERGY, ENTHLP, EPSB1 , EPSB2 , EPSCL , EPSCON,
     5 EPSEND, EPSION, EPST  , EPSTR , EPSWK , EXUK  , GAMMA , GAMMA2,
     6 GI    , KD    , KMAXIN, KMAX  , KMIN  , LASTIT, LNAMAS, LNGAMA,
     7 NP    , PRESHR, RHO   , SMLS  , SS    , SZERO , TAU   , TEMP  ,
     8 THETA , THETAR, THETA2, THETA3, UK2   , UMAX  , ZBAR  , ZSTAR
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
      COMMON/GAL/EX(15),EX1(15),EX2(15)
      COMMON/GALB/EN(1200),K(1920)
      COMMON/GALC/L1,L2,I1,I2,LN1,LN2,NINT1,NINT2,MZERO1,MONE1,KC,KS,
     2          U1,U2,FNSTR1,FNSTR2,FKAPP,DEF1
      COMMON/GALD/SIG1(5,20,13),SIG2(7,11,13),A1(5,20,12),A2(7,11,12)
      COMMON/GALE/SIGB1(5,20,3),SIGB2(7,11,3),SIGF1(5,20),SIGF2(7,11),
     2           AF1(5,20),AF2(7,11)
      DIMENSION EIG(12,7,7),DEFI(12,7,7),D[illegible]AS(12,7),FI1(7,7),
     2 IPRML(7,3),JMAX(7),LHI(7),LI(7),LN[illegible].I(12,7),LNGKI(12,7),
     3 LNFKI(12,7),LNMINI(7),LNPEKI(12,7[illegible]EKI(7)
      DIMENSION APC(300),APL(300),FFTHSR[illegible]),FF2(300),CONT(300),
     2  PLOCAL(300),AROS(300),SAVE(1500,
      DIMENSION FZRO(6),Q(6,6),D2E(6,6),N[illegible]TRNG(10),FTABLE(20),DI(6)
      DATA DI/2.,2.,4.,10.,14.,0./
      DATA FTABLE/.643,.839,.986,1.099,1.189,1.261,1.[illegible].370,1.412,
     2 1.449,1.482,1.511,1.538,1.562,1.584,1.604,1.623,1.641,1.657,0./
      INTEGER BYPASS
      REAL LG,LGW
C
C         ERROR FUNCTION
C
      ERF(X)=   1.-1./((1.+X*(.278393+X*(.230389+X*(9.72E-4+
     2             7.8108E-2*X))))**4)
C
C         EXP(-X)
C
      EXX(Y)=   1./(1. +Y*(.2507213 +Y*(.292732E-1 +.38278E-2*Y)))**4
      MDATA=    0
      KDRUM=    0
      KW=       0
      BYPASS=   0
      IF(IPASS.NE.0) GO TO 5
      IPASS=    1
C
C         INPUT TAPE UNIT
C
      NT=       11
C
```

```
C          TEMPORARY STORAGE DRUM UNITS
C
      ND=        2
      ND2=       3
      READ(NT) (((EIG(K1,K2,K3),K3=1,7),K2=1,7),K1=1,12)
      READ(NT) (((DEFI(K1,K2,K3),K3=1,7),K2=1,7),K1=1,12)
      READ(NT) ((DEFAS(K1,K2),K2=1,7),K1=1,12)
      READ(NT) ((FII(K1,K2),K2=1,7),K1=1,7)
      READ(NT) ((IPRME(K1,K2),K2=1,3),K1=1,7)
      READ(NT) (UMAX(K1),K1=1,7)
      READ(NT) ( LHI(K1),K1=1,7)
      READ(NT) (  LI(K1),K1=1,7)
      READ(NT) ((LNASKI(K1,K2),K2=1,7),K1=1,12)
      READ(NT) (( LNCKI(K1,K2),K2=1,7),K1=1,12)
      READ(NT) (( LNFKI(K1,K2),K2=1,7),K1=1,12)
      READ(NT) (LNMINI(K1),K1=1,7)
      READ(NT) ((LNPEKI(K1,K2),K2=1,7),K1=1,12)
      READ(NT) (NFKI(K1),K1=1,7)
      READ(NT)      (((SIG1(K),K2,K3),K3=1,13),K2=1,20),K1=1,5)
      READ(NT)      (((SIG2(K1,K2,K3),K3=1,13),K2=1,11),K1=1,7)
      READ(NT)      (((A1(K1,K2,K3),K3=1,12),K2=1,20),K1=1,5)
      READ(NT)      (((A2(K1,K2,K3),K3=1,12),K2=1,11),K1=1,7)
      READ(NT)      (((SIGB1(K1,K2,K3),K3=1,3),K2=1,20),K1=1,5)
      READ(NT)      (((SIGB2(K1,K2,K3),K3=1,3),K2=1,11),K1=1,7)
      READ(NT)      ((SIGF1(K1,K2),K2=1,20),K1=1,5)
      READ(NT)      ((SIGF2(K1,K2),K2=1,11),K1=1,7)
      READ(NT)      ((AF1(K1,K2),K2=1,20),K1=1,5)
      READ(NT)      ((AF2(K1,K2),K2=1,11),K1=1,7)
      REWIND NT
      UMAXIN=    UMAX
    5 IF(UMAXIN.NE.0.) GO TO 110
C
C          SELECTS UMAX IF INPUT UMAX .EQ. 0.
C
      UMAX=      10.
      CON=       6.904300*THETA*GAMMA/(ZBAR*ZSTAR*
     2              (POTENT(KD+1)/THETA +1.))
  100 R=         CON*(UMAX**3)*EXP(-UMAX)
      IF(R.LT.EPSEND) GO TO 110
      UMAX=      UMAX +1.
      GO TO 100
  110 MMAX=      INT(UMAX/DELNU)
      IF(MMAX.LE.300) GO TO 120
      CALL ERROR(2.0110)
  120 CON=       9.23787*THETAR*THETAR*ZBAR*ZSTAR/GAMMA
C
C          INITIALIZES CONTINUOUS AND LINE ARRAYS
C
      DO 130 M=1,MMAX
      UM=        (FLOAT(M))*DELNU
      APC(M)=    CON/(UM**3)
  130 APL(M)=    0.
C
C
      WRITE(6,5000) UMAX,DELNU
C
      CALL TICKER(TIMEA)
```

```
C
      MAXPTS=    0
      KION=      KMIN
  140 IF(PK(KION).GT.EPSION) GO TO 160
  150 KION=      KION+1
      IF(KION.LE.KMAX) GO TO 140
      IF(KDRUM.EQ.0) GO TO 1600
      GO TO 1560
  160 I1=        1
  170 L1=        LI(I1)
      NF=        NFKI(I1)
      LNC=       LNCKI(KION,I1)
      LNMN=      LNMINI(I1)
      LNAS=      LNASKI(KION,I1)
      J1=        1
  180 IF(J1.LE.JMAX(I1)) GO TO 190
      I1=        I1+1
      IF(I1.LE.7) GO TO 170
      GO TO 150
  185 J1=        J1+1
      GO TO 180
  190 I2=        IPRME(I1,J1)
      F=         FII(I1,I2)
      L2=        LI(I2)
C
C          PRESSURE IONIZATION TEST
C
      ICON=      1
      TEST=      FLOAT(KION)*TEMP/13.595
  195 J=         1
  200 IF(J.GT.NP) GO TO 240
      EPSJ=      EPS(KION,1,ICON,J)
      IF(EPSJ) 210,220,230
  210 IF(ABS(EPSJ).LE.TEST) GO TO 230
  220 J=         J+1
      GO TO 200
  230 ICON=      ICON+1
      IF(ICON.LE.NSET(KION,1)) GO TO 195
      KU=        1
      GO TO 250
  240 FK=        PKI(KION,ICON)/PK(KION)
      IF(FK.LE.EPSCON) GO TO 230
      KU=        0
      IF(I2.GE.7) GO TO 245
      JION=      100*(KION-1) +15
      DO 242 JJ1= 1,NP
      FZRO(JJ1)=  EN(JION+JJ1)
      JJ2=       JION +NP*(JJ1)
      DO 241 JJ3= 1,NP
  241 Q(JJ1,JJ3)= EN(JJ2+JJ3)
  242 CONTINUE
      TEPS=      FZRO(I2)
      DO 243 JJ1=1,NP
      AN=        NI(KION,ICON,JJ1)
  243 TEPS=      TEPS +AN*Q(JJ1,I2)
  245 CONTINUE
  250 LN1=       LNMN
```

```
      NSAVE=     0
  255 IF(LN1.GT.LNFKI(KION,I1)) GO TO 260
      KT=        0
      EPS1=      EIG(KION,I1,LN1)
      FNSTR1=    FLOAT(KION)/SQRT(-EPS1)
      N1=        NFKI(I1)
      MZERO1=    1
  257 LNW=       LN1
      FNSTRW=    FNSTR1
      FNI=       NI(KION,ICON,I1)
      FLHI=      LHI(I1)
      LGW=       1. -FNI/FLHI
      FW=        FII(12,I1)
      KA=        0
      GO TO 360
  260 IF(KU.EQ.1) GO TO 310
  270 IF(LN1.GT.LNCKI(KION,I1)) GO TO 300
      IF(NI(KION,ICON,I1).EQ.0) GO TO 230
      N1=        NI(KION,ICON,I1)
      EPS1=      EPS(KION,1,ICON,I1)
      FNSTR1=    FLOAT(KION)/SQRT(-EPS1)
      KT=        1
      MZERO1=    1
  280 IF(LN1.EQ.(LNFKI(KION,I1)+1)) GO TO 257
      KA=        1
      GO TO 360
  300 IF(KU.EQ.0) GO TO 230
  310 LN1=       LNCKI(KION,I1)  +1
  320 IF(LN1.GL.LNASKI(KION,I1)) GO TO 330
      KT=        2
      DEF1=      DEFI(KION,I1,LN1)
      FNSTR1=    FLOAT(LN1) -DEF1
      MZERO1=    1
      FMZERO=    DELNU*THETA*(FNSTR1**3)/(2.*FLOAT(KION**2)*13.595)
      MZERO2=    FMZERO
      N1=        1
      GO TO 360
  330 DEF1=      DEFAS(KION,I1)
  340 FNSTR1=    FLOAT(LN1) -DEF1
      FMZERO=  +DELNU*THETA*(FNSTR1**3)/(2.*FLOAT(KION**2)*13.595)
      IF(FMZERO.GT.1.) GO TO 350
      KT=        3
      MZERO1=    1
      MZERO2=    1
      N1=        1
      GO TO 360
  350 KT=        4
      MZERO1=    FMZERO
      MZERO2=    MZERO1
      N1=        1
  360 ARG=       -FLOAT(KION**2)*THETAR/(DELNU*FNSTR1*FNSTR1)
      NINT1=     1 +INT(ARG)
      IF((ARG-INT(ARG)).LT.0.) NINT1= NINT1-1
      GO TO 380
  370 IF(NINT1.GT.0) GO TO 185
      XT1=       1./(.5-FLOAT(NINT1))
      XT2=       SQRT(THETAR/DELNU*FLOAT(KION**2))
```

```
      MZERO1=    .5*XT2*XT1**1.5
      MZERO2=    MZERO1
      FNSTR1=    SQRT(XT1)*XT2
      LN1=       INT(FNSTR1 +DEF1 +.5)
  380 U1=        DELNU*(FLOAT(NINT1) -.5)
      IF(U1.GE.0.) GO TO 185
C
C         PRESSURE IONIZATION TEST ON INITIAL STATE
C
      FNSTR1=    SQRT(-FLOAT(KION**2)*THETAR/U1)
      FNBARK=    SQRT(FLOAT(KION)*THETAR*ZBAR/AJAY)
      IF(FNSTR1.GE.FNBARK) GO TO 185
      IF(KU.EQ.1) GO TO 410
      IF(KT.LE.1) GO TO 390
      CALL ERROR(2,0380)
  390 LN2=       LNPEKI(KION,I2)
  395 IF(LN2.LE.LNCKI(KION,I2)) GO TO 400
      IF(KT.EQ.1) GO TO 430
      LN1=       LN1+1
      GO TO 255
  400 KS=        1
      KVC=       1
      KC=        KION
      EPS2=      TEPS -1
      IF(KT.EQ.1) EPS2=  TEPS -Q(I1,I2)
      MONE1=     1
      MONE2=     1
      IF(EPS2.GE.0.) GO TO 580
      FNSTR2=    SQRT(-FLOAT(KION**2)/EPS2)
      N2=        NI(KION,ICON,I2)
      N2M=       N2 +1
      LG=        1 -N2/LHI(I2)
      IF(LG.EQ.0) GO TO 580
      GO TO 540
  410 IF(KT.NE.1) GO TO 420
      CALL ERROR(2,0410)
  420 LN2=       LNCKI(KION,I2) +1
  430 KC=        KION
      KV=        1
  440 IF(LN2.GE.LNASKI(KC,I2)) GO TO 470
      KS=        2
      IF(KT.GT.1) GO TO 450
      KVC=       2
      GO TO 460
  450 KVC=       1
  460 DEF2=      DEFI(KC,I2,LN2)
      MONE1=     1
      FNSTR2=    FLOAT(LN2) -DEF2
      FMONE=     .5*DELNU*THETA*(FNSTR2**3)/(FLOAT(KC**2)*13.595)
      MONE2=     FMONE
      MONE2=     MAX0(1,MONE2)
      GO TO 540
  470 DEF2=      DEFAS(KC,I2)
  480 FNSTR2=    FLOAT(LN2) -DEF2
      FMONE=     .5*DELNU*THETA*(FNSTR2**3)/(FLOAT(KC**2)*13.595)
      IF(FMONE.GT.1.) GO TO 510
      KS=        3
```

```
      IF(KT.GT.1) GO TO 490
      KVC=      2
      GO TO 500
  490 KVC=      1
  500 MONE1=    1
      MONE2=    1
      GO TO 540
  510 KS=       4
      KAS=      0
      IF(KT.GT.1) GO TO 520
      KVC=      2
      GO TO 530
  520 KVC=      1
  530 MONE1=    FMONE
      MONE2=    MONE1
  540 LS=       1
      N2W=      1
      ARG=      -FLOAT(KC**2)*THETAR/(DELNU*FNSTR2*FNSTR2)
      NINT2=    1 +INT(ARG)
      IF((ARG-INT(ARG)).LT.0.) NINT2= NINT2-1
      GO TO 560
  550 KAS=      1
      IF(NINT2.GT.0) GO TO 560
      XT1=      -1./(FLOAT(NINT2) -.5)
      XT2=      SQRT(FLOAT(KC**2)*THETAR/DELNU)
      MONE1=    .5*XT1+1.5*XT2
      MONE2=    MONE1
      FNSTR2=   SQRT(XT1)*XT2
      LN2=      INT(FNSTR2 +DEF2 +.5)
  560 U2=       DELNU*(FLOAT(NINT2)-.5)
      IF(U2.GE.0) GO TO 570
      FNSTR2=   SQRT(-FLOAT(KC**2)*THETAR/U2)
C
C
  570 IF((NINT2-NINT1).LE.0) GO TO 580
      IF((NINT2-NINT1).LE.MMAX) GO TO 700
C
C
      IF(KS.GT.1) GO TO 630
      LN2=      LN2+1
      GO TO 395
  580 GO TO (590,600,610,620),KS
  590 LN2=      LN2+1
      GO TO 395
  600 LN2=      LN2+1
      GO TO 440
  610 LN2=      LN2+1
      GO TO 480
  620 NINT2=    NINT2+1
      GO TO 550
  630 CONTINUE
      GO TO (640,670),KVC
  640 IF(KT.GT.1) GO TO 650
      CALL ERROR(2,0640)
  650 IF(KT.GT.2) GO TO 655
      LN1=      LN1+1
      GO TO 320
```

```
  655 IF(KT.GT.3)GO TO 660
      LN1=      LN1+1
      GO TO 340
  660 NINT1=    NINT1+1
      GO TO 370
  670 IF((KV.LT.KVC).AND.(KION.GT.KMIN)) GO TO 680
      LN1=      LN1+1
      IF(KT.EQ.0) GO TO 255
      GO TO 270
  680 KC=       KION -1
      KV=       KV+1
      LN2=      LNCKI(KION,I2) +1
      GO TO 440
  700 CONTINUE
      MAXPTS=   MAXPTS +1
      MNINT=    NINT2-NINT1
C
C         TRANSITION FREQUENCY
C
      IF(NINT2.GT.0) MNINT= -MNINT
      FN1=      N1
      FG=       LG
      FKAPP=    FN1*F*FG
C
C         POPULATION OF A STATE
C
      IF(KT.GT.1) GO TO 1070
      IF(KT.EQ.1) GO TO 1040
      GO TO (1000,1010,1010,1010),KS
 1000 IF((KION.EQ.1).OR.(KV.EQ.1)) GO TO 1003
      HK=       1. -UK1(KION-1)/UK(KION-1)
      GO TO 1005
 1003 HK=       0.
 1005 POP=      FK*(PK(KION) +HK*PK(KION-1)*UK(KION)/UK1(KION))
      GO TO 1200
 1010 GO TO (1020,1030),KV
 1020 POP=      PK(KION)*UK1(KION)/UK(KION)
      GO TO 1200
 1030 HK=       1.-UK1(KION-1)/UK(KION-1)
      POP=      PK(KION-1)*HK
      GO TO 1200
 1040 GO TO (1000,1050,1050,1050),KS
 1050 GO TO (1000,1060),KV
 1060 HK=       1.-UK1(KION-1)/UK(KION-1)
      HK=       HK*WKI(KION,1,ICON)/UK1(KION)
      POP=      PK(KION-1)*HK
      GO TO 1200
 1070 IF(LN1.EQ.NSAVE) GO TO 1200
      NSAVE=    LN1
      HK=       1.-UK1(KION)/UK(KION)
      IF(KT.EQ.2.OR.KT.EQ.3) GO TO 1090
      IF(KT.EQ.4) GO TO 1120
 1090 IF(I1.GT.5) GO TO 1100
      IF(LN1.LE.10) GKMIX= GKMI(KION,I1,LN1)
      IF(LN1.GT.10) GKMIX= EXP(THETAR*FLOAT(KION**2)/
     2              (FLOAT(LN1)-DEF(KION,I1 ))**2-POTENT(KION)/THETA)
      POP=      PK(KION)*HK*DI(I1)*GKMIX/EX(KION)
```

```
      GO TO 1200
 1100 CONTINUE
      IF(LN1.LE.10) FMNKX= FMNK(KION,LN1)
      IF(LN1.GT.10) FMNKX= FLOAT(2*LN1*LN1-32)*
     2              EXP(THETAR*FLOAT(KION**2)/FLOAT(LN1*LN1)
     3                -POTENT(KION)/THETA)
      ALN1=      LN1
      IF(I1.NE.6) GO TO 1110
      POP=       PK(KION)*HK*18.*FMNKX/(EX(KION)*
     2              (2.*ALN1*ALN1-32.))
      GO TO 1200
 1110 POP=       PK(KION)*HK*(2.*ALN1*ALN1-50.)*FMNKX/
     2              (EX(KION)*(2.*ALN1*ALN1-32.))
      GO TO 1200
 1120 ARG=       -U1-POTENT(KION)/THETA
      IF(I1.GT.5) GO TO 1130
      POP=       PK(KION)*HK*UI(I1)*EXP(ARG)/EX(KION)
      GO TO 1200
 1130 IF(I1.GT.6) GO TO 1140
      POP=       PK(KION)*HK*18.*EXP(ARG)/EX(KION)
      GO TO 1200
 1140 POP=       PK(KION)*HK*FLOAT(2*LN1*LN1-50)*EXP(ARG)/EX(KION)
C
C          STRENGTH OF THE TRANSITION
C                    BB IS S.T.F. BOUND-BOUND
C                    BD IS BATES-DAMGAARD
C                    BF IS S.T.F. BOUND-FREE
C                    BS IS BURGESS-SEATON
C                    HYD IS HYDROGENIC APPROXIMATION
C
 1200 GO TO (1210,1210,1210,1210,1270,1280,1280),I1
 1210 IF(NINT2.LE.0) GO TO 1220
      IF(FNSTR1.GE.(FLOAT(L1)+.5)) GO TO 1260
      IF(KT.GE.2) GO TO 1260
 1215 CALL BF(THETA,DELNU,KION,QUAN,R)
      GO TO 1399
 1220 IF(FNSTR1.GE.(FLOAT(L1)+.5)) GO TO 1240
 1230 IF(KT.GE.2) GO TO 1250
 1235 CALL BB(KION,QUAN,R)
      GO TO 1399
 1240 IF(FNSTR2.GE.(FLOAT(L2)+.5)) GO TO 1250
      GO TO 1230
 1250 IF((FNSTR2-FNSTR1).GE.1.5) GO TO 1260
      CALL BD(THETA,DELNU,QUAN,R)
      GO TO 1399
 1260 DEFT=      DEFAS(KC,I2)
      CALL BS(THETA,DELNU,KION,DEFT,QUAN,R)
      GO TO 1399
 1270 IF(I2.EQ.4) GO TO 1210
      IF(LN1.EQ.5) GO TO 1275
      CALL HYD(THETA,DELNU,KION,QUAN,R)
      QUAN=      .6428571*QUAN
      GO TO 1399
 1275 IF(NINT2.GT.0) GO TO 1215
      CALL BB(KION,QUAN,R)
      GO TO 1399
 1280 IF((I2.EQ.5).OR.(I2.EQ.7)) GO TO 1290
```

```
      CALL ERROR(2,1280)
 1290 IF(I2.EQ.5) GO TO 1300
      CALL HYD(THETA,DELNU,KION,QUAN,R)
      GO TO 1399
 1300 IF(LN2.EQ.5) GO TO 580
      CALL HYD(THETA,DELNU,KION,QUAN,R)
      QUAN=      .3888889*QUAN
 1399 CONTINUE
C
C          5.1553E+5/MASS*PQ IS TOTAL STRENGTH OF A LINE
C
      PQ=        POP*QUAN
      IF(KW.EQ.1) GO TO 1500
C
C                    CLUSTER WIDTH
C
      IF(ISAVEK.EQ.KION) GO TO 1420
      ISAVEK=    KION
      JION=      100*(KION-1) +57
      DO 1410 JJ1=1,NP
      JJ3=       JION +NP*(JJ1-1)
      DO 1400 JJ2=1,NP
 1400 D2E(JJ1,JJ2)= EN(JJ3+JJ2)
 1410 CONTINUE
 1420 CONTINUE
      GO TO (1430,1450,1450,1450), KS
 1430 IF(KT.GT.0) GO TO 1440
      D=         0.
      Y1=        NI(KION,ICON,I2)
      IF(Y1.EQ.0.) GO TO 1433
      Y2=        DI(I2)
      IF((Y1.EQ.1.).AND.(Y2.EQ.2.)) GO TO 1431
      D=         Y1*(Y2-Y1-1.)/(Y2-2.)*D2E(I2,I2)
      GO TO 1433
 1431 D=         D2E(I2,I2)
 1433 DO 1435 JJ1=1,NP
      IF(JJ1.EQ.I2) GO TO 1435
      Y1=        NI(KION,ICON,JJ1)
      IF(Y1.EQ.0.) GO TO 1435
      Y2=        DI(JJ1)
      D=         D +Y1*(Y2-Y1)/(Y2-1.)*D2E(JJ1,I2)
 1435 CONTINUE
      GO TO 1490
 1440 CONTINUE
      D=         0.
      Y1=        NI(KION,ICON,I1)
      Y2=        DI(I1)
      D=         (Y1-1.)*(Y2-Y1)/(Y2-2.)*D2E(I1,I1)
      Y1=        NI(KION,ICON,I2)
      Y2=        DI(I2)
      D=         D +Y1*(Y2-Y1-1.)/(Y2-2.)*D2E(I2,I2)
      DO 1445 JJ1=1,NP
      IF((JJ1.EQ.I1).OR.(JJ1.EQ.I2)) GO TO 1445
      Y1=        NI(KION,ICON,JJ1)
      IF(Y1.EQ.0.) GO TO 1445
      Y2=        DI(JJ1)
      D=         D +Y1*(Y2-Y1)/(Y2-1.)*.5*(D2E(I1,JJ1)
```

```
     2             +D2E(I2,JJ1))
 1445 CONTINUE
      GO TO 1490
 1450 IF(KT.GT.0) GO TO 1460
      D=          0.
      JJ2=        JMIN(KION,1)
      DO 1455 JJ1=1,NP
      Y1=         NI(KION,JJ2,JJ1)
      IF(Y1.EQ.0.) GO TO 1455
      Y2=         DI(JJ1)
      FNSTRD=     -FLOAT(KION**2)/EPS(KION,1,JJ2,JJ1)
      ARG=        .01*FLOAT((KION-1)**2)*FNSTR1*FNSTR1/(FNSTRD**3)
      D=          D +Y1*(Y2-Y1)/(Y2-1.)*ARG
 1455 CONTINUE
      GO TO 1490
 1460 IF(KT.GT.1) GO TO 1475
      D=          0.
      TD2E=       D2E(I1,I1)
      IF(TD2E.EQ.0.) GO TO 1465
      Y1=         NI(KION,ICON,I1)
      Y2=         DI(I1)
      D=          (Y1-1.)*(Y2-Y1)/(Y2-2.)*TD2E
 1465 DO 1470 JJ1=1,NP
      IF(JJ1.EQ.I1) GO TO 1470
      Y1=         NI(KION,ICON,JJ1)
      Y2=         DI(JJ1)
      D=          D +Y1*(Y2-Y1)/(Y2-1.)*D2E(I1,JJ1)
 1470 CONTINUE
      GO TO 1490
 1475 D=          0.
      JJ2=        JMIN(KION,1)
      DO 1480 JJ1=1,NP
      Y1=         NI(KION,JJ2,JJ1)
      IF(Y1.EQ.0.) GO TO 1480
      Y2=         DI(JJ1)
      FNSTRD=     -FLOAT(KION**2)/EPS(KION,1,JJ2,JJ1)
      ARG=        .01*FLOAT(KION**2)*FNSTRD/(FNSTR1**6)
      D=          D +Y1*(Y2-Y1)/(Y2-1.)*ARG
 1480 CONTINUE
 1490 CONTINUE
      D=          1.414214*CCL*THETAR*SQRT(D)
      IF(KS.GE.4) GO TO 1491
      IF((KT.LT.4).OR.(NINT2.GT.0)) GO TO 1492
 1491 IF(D.GT.(DELNU/2.44949)) GO TO 1492
      D=          FLOAT(MZERO1*MONE1)*D
      D=          AMIN1(D,DELNU/2.44949)
 1492 CONTINUE
C
C                    LINE WIDTH
C
      FLN2=       (FNSTR2 +DEF2)**2
      ARG=        SQRT(POTENT(KION))*POTENT(KION)
      WN=         4.4118E-6*FLOAT(KION**3)*ARG/(FLN2*(FNSTR2**3)*
     2               (POTENT(KION) +U2*THETA))
      WN=         AMAX1(WN,0.)
      WC=         2.*THETA*(FNSTR2**4)/(GAMMA*FLOAT(KC**2))
      WL=         WN +WC
```

```
C
C
      IF(NINT2.LE.0) GO TO 1540
      IF(BYPASS.EQ.0) GO TO 1530
      ARG=       D*ABS(QUAN-SAVEQ)/(DELNU*QUAN)
      IF(ARG.GT.EPSCL) GO TO 1530
      BYPASS=    0
      KW=        1
      DO 1495 M=1,MMAX
 1495 FFTHSR(M)= 0.
      ISAVEM=    ABS(MNINT)
 1500 CONTINUE
      IM=        ABS(MNINT)
      FFTHSR(IM)= PQ
      IF(IM.LT.MMAX) GO TO 580
      FSAVEM=    .5*FFTHSR(ISAVEM)
      CON=       5.
      IF(D.NE.0.) CON= DELNU/D
      DO 1520 M=1,MMAX
      IF(M.GT.ISAVEM) GO TO 1510
      ARG=       CON*FLOAT(ISAVEM-M)
      IF(ARG.GT.4.) ARG= 4.
      APC(M)=    APC(M) +FSAVEM*(1.-ERF(ARG))
      GO TO 1520
 1510 ARG=       CON*FLOAT(M-ISAVEM)
      IF(ARG.GT.4.) ARG= 4.
      APC(M)=    APC(M) +.5*FFTHSR(M)*(1.+ERF(ARG))
 1520 CONTINUE
      KW=        0
      GO TO 580
 1530 BYPASS=    1
      SAVEQ=     QUAN
      KCC=       1
      KSS=       0
      GO TO 1650
 1540 CONTINUE
C
C          NUMBER OF LINES
C
      CALL NLINES(KION,ICON,KT,FLINE)
      IF(KS.LT.3) GO TO 1550
      SR=        WL*(FNSTR2**3)/(27.19*FLOAT(KC**2))
      IF(SR.LT.1.) GO TO 1550
      KCC=       1
      KSS=       0
      GO TO 1650
 1550 CONTINUE
C
C          STORE
C                    MNINT      TRANSITION FREQUENCY
C                    FLINE      NUMBER OF LINES
C                    D          CLUSTER WIDTH
C                    PQ         TOTAL STRENGTH OF A LINE
C                    WL         LINE WIDTH
C
      MDATA=     MDATA +1
      SAVE(MDATA,1)=  MNINT
```

```
      SAVE(MDATA,2)= FLINE
      SAVE(MDATA,3)=  D
      SAVE(MDATA,4)=  PQ
      SAVE(MDATA,5)=  WL
      IF(MDATA.LT.1500) GO TO 580
 1560 KDRUM=     KDRUM +1
      WRITE(ND) ((SAVE(MD1,MD2),MD2=1,5),MD1=1,MDATA)
      IF(KION.GT.KMAX) GO TO 1600
      MDATA=     0
      GO TO 580
 1600 CONTINUE
      KDATA=     MDATA
      REWIND ND
      IDRUM=     KDRUM
      DO 1610 M=1,MMAX
 1610 FF2(M)=    APL(M)
      KCC=       0
      KSS=       0
      MAXPTD=    MDATA
      IF(IDRUM.GT.0) MAXPTD= MAXPTD +1500*(IDRUM-1)
      IF(IDRUM.NE.0) GO TO 1620
      MAXD=      MDATA
      MDATA=     0
      GO TO 1640
 1620 MAXDT=     MDATA
 1630 IDRUM=     IDRUM-1
      MAXD=      1500
      IF(IDRUM.EQ.0) MAXD= MAXDT
      READ(ND) ((SAVE(MD1,MD2),MD2=1,5),MD1=1,MAXD)
      IF(IDRUM.EQ.0) REWIND ND
      MDATA=     0
 1640 MDATA=     MDATA+1
      MNINT=     SAVE(MDATA,1) +.5
      FLINE=     SAVE(MDATA,2)
      D=         SAVE(MDATA,3)
      PQ=        SAVE(MDATA,4)
      WL=        SAVE(MDATA,5)
 1650 NSUM=      ABS(MNINT)
      ARG=       5.
      IF(D.NE.0.) ARG= .5*DELNU/D
      IF(ARG.GT.4.) ARG= 4.
      PHIZRO=    ERF(ARG)
      MSUM=      NSUM
      IF(MNINT.GT.0) GO TO 1660
      APC(MSUM)= APC(MSUM) +PQ*PHIZRO
      JA=        1
      GO TO 1670
 1660 APL(MSUM)= APL(MSUM) +PQ*PHIZRO
      JA=        2
 1670 MSUM=      MSUM+1
      B2=        0.
      PTEMP=     0.
      IF(D.EQ.0.) GO TO 1675
      ARG1=      (FLOAT(MSUM-NSUM)+.5)*DELNU/D
      IF(ARG1.GT.4.) ARG1= 4.
      ARG2=      (FLOAT(MSUM-NSUM)-.5)*DELNU/D
      IF(ARG2.GT.4.) ARG2= 4.
```

```
      PHIMN=     .5*(LRF(ARG1)-LRF(ARG2))
      PTEMP=     PQ*PHIMN
      B2=        PHIMN/PHIZRO
 1675 DELM=      FLOAT(MSUM)*DELNU
      B1=        0.
      IF(DELM.GT.UMAX) GO TO 1680
      IF(JA.EQ.1) APC(MSUM)= APC(MSUM) +PTEMP
      IF(JA.EQ.2) APL(MSUM)= APL(MSUM) +PTEMP
      B1=        PTEMP/(APC(MSUM)+APL(MSUM))
 1680 B3=        0.
      NM2=       2*NSUM-MSUM
      IF(NM2.LT.1) GO TO 1690
      IF(JA.EQ.1) APC(NM2)=  APC(NM2) +PTEMP
      IF(JA.EQ.2) APL(NM2)=  APL(NM2) +PTEMP
      B3=        PTEMP/(APC(NM2) +APL(NM2))
 1690 IF((B1.GE.EPSB1).OR.(B2.GE.EPSB2).OR.(B3.GE.EPSB1)) GO TO 1670
      IF(KCC.EQ.1) GO TO 580
      IF(KSS.EQ.1) GO TO 1840
      IF(MDATA.LT.MAXD) GO TO 1640
      IF(IDRUM.EQ.0) GO TO 1700
      GO TO 1630
 1700 CONTINUE
      CON=       5.1553E+5/AMASS
      NMSH=      MMAX
      TEMPE1=    EXP(-DELNU)
      TEMPE2=    SQRT(TEMPE1)
      TEMPE3=    EXP(DELNU)
      DO 1710 M=1,MMAX
      APC(M)=    CON*APC(M)
      APL(M)=    CON*APL(M)
      PLOCAL(M)= APC(M) +APL(M)
      CONT(M)=   APC(M)
 1710 CONTINUE
C
C          CALCULATE PLANCK CONTINUOUS AND PLANCK MEAN
C
      MMAX1=     MMAX -1
      TEMPE4=    MMAX**3
      TEMPE5=    TEMPE1**MMAX
      PKAP1=     (1. -TEMPE2)*APC(1)/DELNU +.5*TEMPE4*TEMPE5*APC(MMAX)
      PKAP2=     .5*(TEMPE1*PLOCAL(1) +TEMPE4*TEMPE5*PLOCAL(MMAX))
      TEMPE2=    TEMPE1
      DO 1720 MSH=1,MMAX1
      FMSH=      MSH**3
      PKAP1=     PKAP1 +FMSH*APC(MSH)*TEMPE2
      PKAP2=     PKAP2 +FMSH*PLOCAL(MSH)*TEMPE2
 1720 TEMPE2=    TEMPE2*TEMPE1
      PKAP1=     .1539897*(DELNU**4)*PKAP1
      PKAP2=     .1539897*(DELNU**4)*PKAP2
      TEMPE2=    TEMPE1
      TEMPE4=    TEMPE4*FLOAT(MMAX)
      TEMPE5=    TEMPE1**MMAX
      RKAP1=     (6.25E-3 +5.20833E-3*DELNU)/((DELNU**3)*APC(1)) +
     2           .5*TEMPE4*TEMPE5/(((1.-TEMPE5)**3)*APC(MMAX))
C
C          CALCULATE ROSSELAND CONTINUOUS
C
```

```
      DO 1730 MSH=1,MMAX1
      FMSH=     MSH**4
      TEMPE5=   1./((1.-TEMPE2)**3)
      RKAP1=    RKAP1 +FMSH*TEMPE2*TEMPE5/APC(MSH)
      TEMPE2=   TEMPE2*TEMPE1
 1730 CONTINUE
      RKAP1=    3.849743E-2*(DELNU**5)*RKAP1
      RKAP1=    1./RKAP1
      DO 1740 M=1,MMAX
      APC(M)=   APC(M)/CON
      APC(M)=   APC(M) +FF2(M)
      APL(M)=   0.
 1740 CONTINUE
      NWKPTS=   0
      NST=      0
C
      IDRUM=    KDRUM
      IF(IDRUM.NE.0) GO TO 1800
      MAXD=     KDATA
      MDATA=    0
      NSPTS=    0
      GO TO 1820
 1800 MAXDT=    KDATA
 1810 IDRUM=    IDRUM -1
      MAXD=     1500
      IF(IDRUM.EQ.0) MAXD= MAXDT
      READ(ND) ((SAVE(MD1,MD2),MD2=1,5),MD1=1,MAXD)
      IF(IDRUM.EQ.0) REWIND ND
      NSPTS=    0
      MDATA=    0
 1820 MDATA=    MDATA +1
      MNINT=    SAVE(MDATA,1) +.5
      FLINE=    SAVE(MDATA,2)
      D=        SAVE(MDATA,3)
      PQ=       SAVE(MDATA,4)
      WL=       SAVE(MDATA,5)
C
C         SELECT WEAK CLUSTERS
C
      WBAR=     WL/THETA
      DMAX=     AMAX1(D,WBAR)
      SDE=      PQ*DELNU/DMAX
      IM=       ABS(MNINT)
      TEST=     APC(IM)
      ARG=      SDE/(1.772454*TEST)
      IF(ARG.GT.EPSWK) GO TO 1825
      KSS=      1
      NWKPTS=   NWKPTS +1
      GO TO 1650
 1825 NSPTS=    NSPTS +1
      SAVE(NSPTS, 1)=  MNINT
      SAVE(NSPTS, 2)=  FLINE
      SAVE(NSPTS, 3)=  D
      SAVE(NSPTS, 4)=  PQ
      SAVE(NSPTS, 5)=  WL
 1840 IF(MDATA.LT.MAXD) GO TO 1820
      NTOT=     NSPTS
```

```
      IF(KDRUM.EQ.0) GO TO 1905
      WRITE(ND2) ((SAVE(MD1,MD2),MD2=1,5),MD1=1,NSPTS)
      NST=       NST +1
      NSTRNG(NST)= NSPTS
      IF(IDRUM.EQ.0) GO TO 1900
      GO TO 1810
 1900 REWIND ND2
      NTOT=      0
      MD3=       1
      DO 1920 M=1,NST
      NSPTS=     NSTRNG(M)
      NTOT=      NTOT +NSPTS
      READ(ND2)  ((SAVE(MD1,MD2),MD2=1,5),MD1=MD3,NTOT)
 1920 MD3=       NTOT +1
      REWIND ND2
      IF(NTOT.GT.1500) CALL ERROR(2,1920)
 1905 DO 1910 M=1,MMAX
 1910 FF2(M)=    CON*(APC(M) +APL(M))
C
C          CALCULATES TRANSMISSIONS
C
      KROS=      1
      BIGXLN=    ALOG(BIGX)
 2000 DMASS1=    0.
      FKAP1=     PLOCAL(KROS)
      TKAP1=     1.
      NR=        1
      TINTU=     0.
 2010 DMASS2=    DMASS1 -BIGXLN/FKAP1
      TKAP2=     EXX(DMASS2*FF2(KROS))
      MDATA=     0
 2020 MDATA=     MDATA +1
      MNINT=     SAVE(MDATA,1) +.5
      FLINE=     SAVE(MDATA,2)
      D=         SAVE(MDATA,3)
      PG=        SAVE(MDATA,4)
      WL=        SAVE(MDATA,5)
      GO TO 2090
 2030 TKAPJ=     AMAX1(TKAPJ,0.)
      TKAPJ=     AMIN1(TKAPJ,1.)
      TKAP2=     TKAP2*TKAPJ
      IF(TKAP2.LE.0.) GO TO 2040
 2035 IF(MDATA.LT.NTOT) GO TO 2020
      FKAP2=     -ALOG(TKAP2)/DMASS2
      FKAP2=     AMIN1(FKAP1,FKAP2)
      DTINTU=    (TKAP1 -TKAP2)*(DMASS2 -DMASS1)/(DMASS2*FKAP2 -DMASS1*
     2           FKAP1)
      TINTU=     TINTU +DTINTU
      ARG=       TKAP2/(FF2(KROS)*TINTU)
      IF(ARG.LE.EPST) GO TO 2045
      NR=        NR +1
      DMASS1=    DMASS2
      FKAP1=     FKAP2
      TKAP1=     TKAP2
      GO TO 2010
 2040 TKAP2=     0.
 2045 AROS(KROS)= 1./(TINTU +TKAP2/FF2(KROS))
```

```
      KROS=     KROS +1
      IF(KROS.LE.MMAX) GO TO 2000
C
C         CALCULATE ROSSELAND MEAN
C
      TEMPE2=   TEMPE1
      TEMPE4=   MMAX**4
      TEMPE5=   TEMPE1**MMAX
      RKAP2=    TEMPE5*(6.25E-5+2.60416E-5*DELNU)/((DELNU**3)*AROS(1))+
     2          .5*TEMPE4*TEMPE5/(((1.-TEMPE5)**3)*AROS(MMAX))
      DO 2050 MSH=1,MMAX1
      FMSH=     MSH**4
      TEMPE5=   1./((1.-TEMPE2)**3)
      RKAP2=    RKAP2 +FMSH*TEMPE2*TEMPE5/AROS(MSH)
      TEMPE2=   TEMPE2*TEMPE1
 2050 CONTINUE
      RKAP2=    3.849743E-2*(DELNU**5)*RKAP2
      RKAP2=    1./RKAP2
      U1=       POTENT(KD+1)/THETA
      IF(UMAX.LT.U1) GO TO 2053
      UM=       U1
      U1=       UMAX
      GO TO 2055
 2053 UM=       UMAX
 2055 ARG1=     0.
      ARG2=     1.
      DO 2060 M=1,7
      ARG1=     ARG1 +ARG2
      ARG2=     ARG2*FLOAT(8-M)/U1
 2060 CONTINUE
      ERKROS=   4.0438479E-9*AMASS*GAMMA*RKAP2*(U1**7)/(ZBAR*ZSTAR*
     2          THETAR*THETAR)
      IF(UMAX.GE.U1) GO TO 2063
      ARG=      .13533528
      ERKROS=   ERKROS*(ARG**UM +(ARG**U1)*(2.*ARG1 -1.))
      GO TO 2065
 2063 ERKROS=   ERKROS*(2.*ARG1*EXP(-UM-UMAX))
 2065 CONTINUE
      DO 2070 M=1,MMAX
      FMSH=     M
 2070 APC(M)=   FMSH*DELNU
      WRITE(6,5001)
      WRITE(6,5002)  (APC(M),CONT(M),PLOCAL(M),AROS(M),M=1,MMAX)
      WRITE(6,5003) PKAP1,PKAP2,RKAP1,RKAP2
C
      CALL TICKER(TIMEB)
C
      TIMEC=    (TIMEB-TIMEA)/(FLOAT(MAXPTS)*60.)
      WRITE(6,5004) ERKROS,TIMEC,MAXPTS,MAXPTU,NWKPTS,NTOT
      RETURN
C
C
 2090 CONTINUE
      S=        CON*DELNU*PQ
      WBAR=     WL/THETA
      IF(D.NE.0.) GO TO 2100
      A=        1.
```

```
      HA=       .56418958
      ARG1=     WBAR*DMASS2*S/3.1415927
      ARG2=     WBAR*WBAR +ARG1/FLINE
      TBAR=     ARG1/(ARG2*FLINE)
      IF((TBAR*FLINE).LT.EPSTR) GO TO 2035
      SMLD=     SQRT(ARG2)
      N1=       0
      GO TO 2110
 2100 CONTINUE
      A=        SQRT((WBAR*WBAR+DMASS2*WBAR*S/(3.1415927*FLINE))/(D*D))
      HA=       1. +.7107332*A
      HA=       HA/(1. +1.772454*A*HA)
      TBAR=     WBAR*DMASS2*S*HA/(1.772454*A*D*D*FLINE)
      IF((TBAR*FLINE).LT.EPSTR) GO TO 2035
      N1=       1
 2110 SMLB=     SMLD
      IF(N1.EQ.1) SMLB=   D
      SMLX=     ABS(DELNU/SMLB*FLOAT(KROS -MNINT))
      IF(SMLX.EQ.0.) GO TO 2120
      ARG=      .5*DELNU/SMLB
      ARG1=     SMLX +ARG
      AR 2=     SMLX -ARG
      HBAR1=    HF(N1,A,ARG1,HA)
      HBAR2=    HF(N1,A,ARG2,HA)
      TKAPJ=    TF(TBAR,FLINE,HBAR1,HBAR2)
      GO TO 2030
 2120 TZERO=    (1. -TBAR)**FLINE
      ARG=      .5*DELNU/SMLB
      HBAR1=    HF(N1,A,ARG,HA)
      IF(FLINE.LE.10.) TONE= (1.-TBAR*HBAR1)**FLINE
      IF(FLINE.GT.10.) TONE= EXP(-TBAR*FLINE*HBAR1)
      HBAR2=    1.
      AZERO=    1 -TZERO
      AONE=     1 -TONE
      TDIFF=    TONE -TZERO
      AFRACT=   AZERO/AONE
      N2=       1
      IF(AFRACT.LE.GI) N2= 2
      IF(AFRACT.LT.2.) N2= 3
      IF(TZERO.GT..75) GO TO 2150
      GO TO (2210,2180,2170),N2
 2150 N2=       2
      IF(TDIFF.LE..2) N2= 3
      GO TO (2160,2180,2170),N2
 2160 CALL ERROR(2,2160)
 2170 TKAPJ=    TF(TBAR,FLINE,HBAR1,HBAR2)
      GO TO 2030
 2180 XEND=     .5*DELNU/SMLD
      INT1=     XEND/CGMESH
      DELTA=    XEND/FLOAT(INT1)
      ARG=      .5*DELTA
      HBAR1=    HF(N1,A,ARG,HA)
      HBAR2=    1.
      TINT=     TF(TBAR,FLINE,HBAR1,HBAR2)
      GH=       .5*TINT
      INT2=     1
 2190 FINT2=    INT2
```

```
      XINT=     FINT2*DELTA
      ARG1=     XINT +ARG
      ARG2=     XINT -ARG
      HBAR1=    HF(N1,A,ARG1,HA)
      HBAR2=    HF(N1,A,ARG2,HA)
      TINT=     TF(TBAR,FLINE,HBAR1,HBAR2)
      GR=       GR +TINT
      IF(INT2.GE.(INT1-1)) GO TO 2200
      INT2=     INT2 +1
      GO TO 2190
 2200 HBAR1=    HF(N1,A,XEND,HA)
      HBAR2=    HF(N1,A,XEND-ARG,HA)
      TINT=     TF(TBAR,FLINE,HBAR1,HBAR2)
      GR=       GR +TINT
      TKAPJ=    GR/FLOAT(INT1)
      GO TO 2030
 2210 TBAR=     FLINE*TBAR
      IF(N1.EQ.1) GO TO 2220
      ARG=      TBAR*TBAR
      WSTR2=    SQRT(ARG*(1. +.5*TBAR)/(1. +.9*TBAR +.3925*ARG))
      GO TO 2260
 2220 ARG=      TBAR*TBAR
      WSTR=     4.*ARG*(1. +TBAR)/(1. +1.8*TBAR +1.57*ARG)
      IF(TBAR.GE.1.) GO TO 2230
      FTBAR=    .8862269*TBAR*(1. -TBAR*(.3535534 -TBAR*(.9622504E-1 -
     2          TBAR*(.2063333E-1 -.3726678-2.*TBAR))))
      GO TO 2250
 2230 IF(TBAR.LE.10.) GO TO 2240
      ARG1=     ALOG(TBAR)
      FTBAR=    SQRT(ARG1)*(1. +.2886/ARG1)
      GO TO 2250
 2240 IF1=      2.*TBAR
      FI=       .5*FLOAT(IF1)
      IF2=      IF1
      IF1=      IF1-1
      FTBAR=    2.*(TBAR-FI)*(FTABLE(IF2) -FTABLE(IF1)) +FTABLE(IF1)
 2250 WSTR1=    1.128379*TBAR
      ARG1=     1.772454*A*HA
      WSTR2=    SQRT(ARG1*WSTR +(1. -ARG1)*WSTR1*WSTR1)
 2260 ARG=      1. -1.772454*SRLB*WSTR2/(DELNU*HA)
      TKAPJ=    AMAX1(ARG,0.)
      GO TO 2030
C
C       OUTPUT FORMATS
C
 5000 FORMAT(1H0,2X,4HUMAX,5X,7HDELTA U,/1X,F6.2,6X,F6.2)
 5001 FORMAT(1H0,3X,1HU,10X,10HCONTINUOUS,7X,12HLOCAL PLANCK,4X,15HLOCAL
     2 ROSSELAND,/17X,7H(CM2/G),11X,7H(CM2/G),10X,7H(CM2/G))
 5002 FORMAT((1X,0PF6.2,3(8X,1PE10.4)))
 5003 FORMAT(1H0,4X,12HPLANCK CONT.,3X,11HPLANCK MEAN,2X,15HROSSELAND CO
     2NT.,1X,14HROSSELAND MEAN,/8X,7H(CM2/G),8X,7H(CM2/G),8X,7H(CM2/G),8
     3X,7H(CM2/G),/6X,4(1PE10.4,5X))
 5004 FORMAT(1H0,2(1PE10.4),4I8)
      END
```

```
QI FOR BB/A
      SUBROUTINE BB(K,QUAN,R)
C
C          S.T.F. BOUND-BOUND TABLE
C
      COMMON/GALC/L1,L2,I1,I2,LN1,LN2,NINT1,NINT2,MZERO1,MONE1,KC,KS,
     2            U1,U2,FNSTR1,FNSTR2,FKAPP,DEF1
      COMMON/GALE/SIGB1(5,20,3),SIGB2(7,11,3),SIGF1(5,20),SIGF2(7,11),
     2            AF1(5,20),AF2(7,11)
      DIMENSION ITT(5,6)
      DATA ITT/0,3,5,2*0,1,2*0,7,0,2,2*0,8,2*0,4,6,0,10,3*0,9,5*0,11/
      KION=       K
      IN=         LN2 -4
      IT=         0
      IF(LN1.EQ.6) IT= 11
      IT=         IT +ITT(I1,I2)
      CON=        6.366198
      CON1=       .01
      IF(KION.LE.2) CON= 20.13168
      IF(KION.LE.2) CON1= .001
C       IF K.LE.2  CON=2./(PI*SQRT(1.E-3))
C      OTHERWISE  CON= 2./(PI*1.E-1)
      IF(KION.GT.5) GO TO 20
      IF(LN2.GE.8) GO TO 10
      SIGR=       SIGB1(KION,IT,IN)
      GO TO 50
   10 S1=         SIGF1(KION,IT)
      S12=        S1*S1
      A=          AF1(KION,IT)
      GO TO 40
   20 KION=       KION -5
      IF(LN2.GE.8) GO TO 30
      SIGR=       SIGB2(KION,IT,IN)
      GO TO 50
   30 S1=         SIGF2(KION,IT)
      S12=        S1*S1
      A=          AF2(KION,IT)
   40 CONTINUE
      FN2=        FNSTR2*FNSTR2
      FN3=        FNSTR2*FN2
      A=          0.
      SIGR=       CON*FLOAT(K**2)*S12/FN3*(1. +A/CON1*FLOAT(K**2)/FN2)
   50 FL=         AMAX0(L1,L2)
      FM0=        MZERO1
      FM1=        MONE1
      FN=         NINT2 -NINT1
      R=          (4.*FL*FL -1.)*SIGR
      QUAN=       3.1415927*FM0*FM1*FN*FKAPP*R
      RETURN
      END
```

```
QI FOR BD/A
      SUBROUTINE BD(T,D,QUAN,R)
C
C          BATES-DAMGAARD TABLE
C
      COMMON/GALC/L1,L2,I1,I2,LN1,LN2,NINT1,NINT2,MZERO1,MONE1,KC,KS,
     2          U1,U2,FNSTR1,FNSTR2,FKAPP,DEF1
      DIMENSION TABLE1(31,4),TABLE2(31,4),TABLE3(31,4)
      DATA TABLE1/-1.5,-1.4,-1.3,-1.2,-1.1,-1.0,-.9,-.8,-.7,-.6,-.5,
     2          -.4,-.3,-.2,-.1,0.,.1,.2,.3,.4,.5,.6,.7,.8,.9,1.0,1.1,
     3          1.2,1.3,1.4,1.5,.026,.048,.080,.123,.180,.248,.329,
     4          .418,.514,.612,.708,.797,.875,.937,.980,1.000,.996,
     5          .967,.915,.842,.749,.643,.528,.409,.292,.181,.081,
     6          -.004,-.071,-.120,-.149,-.046,-.015,.028,.084,.154,
     7          .235,.327,.425,.527,.629,.725,.813,.888,.946,.984,1.000,
     8          .992,.961,.908,.835,.745,.642,.531,.417,.304,.198,.102,
     .          .019,-.047,-.096,-.128,-.063,-.031,.014,.072,.145,.229,
     .          .323,.425,.528,.632,.730,.818,.892,.949,.985,1.000,.992,
     .          .960,.906,.831,.743,.642,.532,.420,.309,.204,.108,.025,
     .          -.040,-.089,-.122/
      DATA TABLE2/-1.5,-1.4,-1.3,-1.2,-1.1,-1.0,-.9,-.8,-.7,-.6,-.5,
     2    -.4,-.3,-.2,-.1,0.,.1,.2,.3,.4,.5,.6,.7,.8,.9,1.,1.1,1.2,1.3,
     3    1.4,1.5,.131,.182,.242,.311,.388,.472,.559,.648,.734,.814,
     4    .885,.944,.987,1.011,1.016,1.000,.963,.907,.834,.746,.646,
     5    .540,.431,.324,.222,.129,.049,-.017,-.067,-.101,-.120,.006,
     6    .055,.117,.190,.273,.364,.461,.560,.657,.750,.833,.903,.957,
     7    .993,1.007,1.000,.971,.921,.852,.767,.670,.564,.455,.346,.242,
     8    .147,.063,-.006,-.060,-.097,-.119,-.048,-.004,.053,.123,.205,
     9    .298,.398,.501,.604,.703,.794,.872,.935,.978,1.000,1.000,.997,
     .    .933,.868,.786,.691,.587,.479,.369,.264,.166,.080,.008,-.050,
     .    -.091,-.116/
      DATA TABLE3/-1.5,-1.4,-1.3,-1.2,-1.1,-1.0,-.9,-.8,-.7,-.6,-.5,
     2    -.4,-.3,-.2,-.1,0.,.1,.2,.3,.4,.5,.6,.7,.8,.9,1.0,1.1,1.2,
     3    1.3,1.4,1.5,.244,.313,.389,.471,.557,.644,.731,.813,.888,.952,
     4    1.004,1.040,1.058,1.058,1.038,1.000,.944,.872,.786,.691,.588,
     5    .483,.379,.279,.186,.105,.035,-.020,-.061,-.088,-.101,.047,
     6    .113,.190,.276,.370,.469,.569,.668,.761,.845,.916,.972,1.010,
     7    1.028,1.024,1.000,.955,.892,.813,.722,.621,.515,.409,.305,.209,
     8    .122,.047,-.013,-.059,-.089,-.105,-.007,.051,.123,.206,.298,
     9    .397,.500,.603,.703,.794,.874,.938,.985,1.012,1.017,1.000,
     .    .962,.904,.829,.740,.641,.535,.428,.323,.224,.134,.057,-.007,
     .    -.055,-.088,-.107/
      THETA=    T
      DELNU=    D
      FL1=      L1
      FL2=      L2
      IF((L2-L1).EQ.1) GO TO 10
      L=        L1
      FKNSTR=   FNSTR1
      GO TO 20
   10 L=        L2
      FKNSTR=   FNSTR2
   20 FL=       L
      DELTAN=   (FL2-FL1)*(FNSTR1-FNSTR2)
      IF((DELTAN.LT.(-1.5)).OR.(DELTAN.GT.1.5)) GO TO 999
      J1=       17.+10.*DELTAN
      J2=       J1-1
```

```
      IF(DELTAN.EQ.1.5) J1=   J2
      DX=       (DELTAN-TABLE1(J2,1))/.1
      GO TO (30,40,50),L
   30 AI=       DX*(TABLE1(J1,2)-TABLE1(J2,2)) +TABLE1(J2,2)
      BI=       DX*(TABLE1(J1,3)-TABLE1(J2,3)) +TABLE1(J2,3)
      CI=       DX*(TABLE1(J1,4)-TABLE1(J2,4)) +TABLE1(J2,4)
      FI=       3.125*CI-2.25*BI+.125*AI
      FJ=       -12.5*CI+13.5*BI-AI
      FK=       9.375*CI-11.25*BI+1.875*AI
      GO TO 60
   40 AI=       DX*(TABLE2(J1,2)-TABLE2(J2,2)) +TABLE2(J2,2)
      BI=       DX*(TABLE2(J1,3)-TABLE2(J2,3)) +TABLE2(J2,3)
      CI=       DX*(TABLE2(J1,4)-TABLE2(J2,4)) +TABLE2(J2,4)
      FI=       2.6667*CI -2.*BI +.3333*AI
      FJ=       -8.*CI+10.*BI-2.*AI
      FK=       5.3333*CI-8.*BI+2.6667*AI
      GO TO 60
   50 AI=       DX*(TABLE3(J1,2)-TABLE3(J2,2)) +TABLE3(J2,2)
      BI=       DX*(TABLE3(J1,3)-TABLE3(J2,3)) +TABLE3(J2,3)
      CI=       DX*(TABLE3(J1,4)-TABLE3(J2,4)) +TABLE3(J2,4)
      FI=       4.5*CI -4.*BI +.5*AI
      FJ=       -13.5*CI+16.*BI-2.5*AI
      FK=       9.*CI-12.*BI+3.*AI
   60 FIN=      FI +FJ/(FKNSTR-FL) +FK/(FKNSTR-FL)**2
      F2=       ((1.5*FKNSTR)**2)*((FKNSTR*FKNSTR-FL*FL)/(4.*FL*FL-1.))
      R=        (4.*FL*FL-1.)*F2*FIN*FIN/FLOAT(KC**2)
      RK=       FKAPP*R
      FM0=      MZERO1
      FM1=      MONE1
      QUAN=     3.14159*FM0*FM1*FLOAT(NINT2-NINT1)*RK
      RETURN
  999 CALL ERROR(3,0999)
      RETURN
      END
```

```
@I FOR BF/A
      SUBROUTINE BF(T,D,K,QUAN,R)
C
C          S.T.F. BOUND-FREE TABLE
C
      COMMON/GALC/L1,L2,I1,I2,LN1,LN2,NINT1,NINT2,MZERO1,MONE1,KC,KS,
     2            U1,U2,FNSTR1,FNSTR2,FKAPP,DEF1
      COMMON/GALD/SIG1(5,20,13),SIG2(7,11,13),A1(5,20,12),A2(7,11,12)
      DIMENSION E1(16),ITT(5,6)
      DATA E1/.001,.003,.007,.01,.03,.07,.1,.3,.7,1.,3.,7.,10.,30.,70.,
     2          100./
      DATA ITT/0,3,5,2*0,1,2*0,7,0,2,2*0,8,2*0,4,6,0,10,3*0,9,5*0,11/
      THETA=    T
      DELNU=    D
      KION=     K
      E=        (FLOAT(NINT2)-.5)*DELNU*THETA/13.595
      IT=       0
      IF(LN1.EQ.6) IT= 11
      IT=       IT +ITT(I1,I2)
      IE=       0
      IF(KION.GT.2) IE= 3
      IF(KION.GT.5) GO TO 40
      DO 10 I=1,13
      J=        I -1
      II=       IE +I
      IF(E.LE.E1(II)) GO TO 15
   10 CONTINUE
      GO TO 30
   15 IF(J.EQ.0) GO TO 25
      S1=       SIG1(KION,IT,J)
      S2=       SIG1(KION,IT,J+1)
      TEST=     S1*S2
      IF(TEST.LE.0.) GO TO 35
      A=        A1(KION,IT,J)
   20 S12=      S1*S1
      JJ=       J+ IE
      EJ=       SQRT(E1(JJ))
      SIGR=     S12*((E1(JJ)/E)**A)/EJ
      GO TO 100
   25 A=        0.
      J=        1
      S1=       SIG1(KION,IT,J)
      GO TO 20
   30 J=        13
      A=        A1(KION,IT,J-1)
      S1=       SIG1(KION,IT,J)
      GO TO 20
   35 JJ=       J +IE
      ARG=      1./SQRT(E)
      SIGR=     ARG*(S1 +(S2-S1)*(E-E1(JJ))/(E1(JJ+1)-E1(JJ)))**2
      GO TO 100
   40 KION=     KION -5
      DO 45 I=1,13
      J=        I -1
      II=       IE +I
      IF(E.LE.E1(II)) GO TO 50
   45 CONTINUE
```

```
      GO TO 60
   50 IF(J.LQ.0) GO TO 55
      S1=        SIG2(K1ON,IT,J)
      S2=        SIG2(K1ON,IT,J+1)
      TEST=      S1*S2
      IF(TEST.LE.0.) GO TO 55
      A=         A2(K1ON,IT,J)
      GO TO 20
   55 A=         0.
      J=         1
      S1=        SIG2(K1ON,IT,J)
      GO TO 20
   60 J=         13
      A=         A2(K1ON,IT,J-1)
      S1=        SIG2(K1ON,IT,J)
      GO TO 20
  100 FM0=       MZERO1
      FN=        NINT2-NINT1
      FL=        AMAX0(L1,L2)
      R=         (4.*FL*FL -1.)*SIGR
      QUAN=      FM0*FN*FKAPP*DELNU*THETA*R/13.595
      RETURN
      END
```

```
QI FOR,S/A
      SUBROUTINE BS(T,D,K,DEFT,QUAN,R)
C
C          BURGESS-SEATON TABLE
C
      COMMON/GALC/L1,L2,I1,I2,LN1,LN2,NINT1,NINT2,MZERO1,MONE1,KC,KS,
     2           U1,U2,FNSTR1,FNSTR2,FKAPP,DEF1
      DIMENSION TABB(11)
      DIMENSION TABA1(6,12),TABA2(6,12)
      DATA TABB/.079,.069,.054,.038,.029,.035,.053,.068,.068,.060,.05/
      DATA TABA1/.079109,.061968,.27713,.038162,.020467,.012347,.15048,
     2.13139,.64795,.097223,.063532,.040030,.43711,.38209,1.1126,.28140,
     3.18790,.11143,.68375,.609490,1.6384,.46521,.32995,.19896,.67382,
     4.61848,.59238,.50267,.50524,.25372,.90675,.83874,.80434,.69236,
     5.54649,.36991,1.1651,1.0844,1.0410,.90674,.72924,.51178,1.4476,
     61.3540,1.3010,1.1442,.93443,.68003,1.7539,1.6467,1.5835,1.4039,
     71.1614,.87296,2.0821,1.9618,1.8876,1.6852,1.4095,1.0883,2.4310,
     82.2985,2.2130,1.9876,1.6784,1.3247,2.8017,2.6561,2.5588,2.3103,
     91.9670,1.5815/
      DATA TABA2/-.13553,-.40245,-.11759,-.37608,.12169,-.027141,
     2-.099951,-.21100,-.12975,-.19184,.18918,.23255,-.056456,-.076642,
     3-.082499,-.11127,.074583,.052754,-.036231,-.050687,-.042033,
     4-.074741,.0058416,.056438,-.024874,-.035247,-.035617,-.048402,
     5-.0093181,.080918,-.019320,-.026714,-.027022,-.036132,-.017579,
     6.10572,-.015177,-.020643,-.021309,-.027308,-.016537,.11701,
     7-.012091,-.017009,-.016691,-.021592,-.015225,.10488,-.010104,
     8-.013847,-.013879,-.017942,-.013263,.080003,-.0084679,-.011461,
     9-.011445,-.014660,-.011745,.056601,-.0054889,-.0089921,-.0090365,
     *-.012003,-.0099834,.039851,-.0044566,-.0074882,-.0072591,-.010341,
     *-.0085944,.028671/
      THETA=     T
      DELNU=     D
      KION=      K
      E1=        (FLOAT(NINT2)-.5)*DELNU*THETA/13.595
      DEF2=      DEFT +TABA2(I2,KC)*(E1 +TABA1(I2,KC))
      E=         1.-U2/U1
      L=         L1+1
      LP=        L2+1
      GO TO (10,55,140,175),L
   10 ALPHA=     .25
      BETA=      0.
      IF(FNSTR1-1.) 15,25,20
   15 GA=        1.287
      GB=        1.855
      GC=        -.432
      GAMA=      1.268
      GAMB=      .560
      GAMC=      -.126
      CHIA=      -.179
      CHIB=      .265
      CHIC=      -.043
      GO TO 180
   20 IF(FNSTR1-1.4) 25,35,30
   25 GA=        1.086
      GB=        2.111
      GC=        -.458
      GAMA=      1.667
```

```
      GAMB=       .255
      GAMC=       .290
      CHIA=       -.0545
      CHIB=       -.0159
      CHIC=       .113
      GO TO 180
   30 IF(FNSTR1-2.) 35,45,40
   35 GA=         1.655
      GB=         .629
      GC=         .5
      GAMA=       1.549
      GAMB=       .0944
      GAMC=       .0299
      CHIA=       -.174
      CHIB=       .344
      CHIC=       -.157
      GO TO 180
   40 IF(FNSTR1-6.) 45,50,50
   45 GA=         1.164
      GB=         2.57
      GC=         -1.416
      GAMA=       1.594
      GAMB=       0.
      GAMC=       0.
      CHIA=       -.147
      CHIB=       .2515
      CHIC=       -.078
      GO TO 180
   50 GA=         .996
      GB=         4.602
      GC=         -7.56
      GAMA=       1.598
      GAMB=       0.
      GAMC=       0.
      CHIA=       -.147
      CHIB=       .2515
      CHIC=       -.078
      GO TO 180
   55 IF(FNSTR1.LT.1.) GO TO 999
      GO TO (60,999,95) ,LP
   60 ALPHA=      0.
      BETA=       0.
      IF(FNSTR1-2.) 65,75,70
   65 GA=         .6617*SQRT(FNSTR1-1.)
      GB=          .131*SQRT(FNSTR1-1.)
      GC=         1.087*SQRT(FNSTR1-1.)
      GAMA=       1.5017
      GAMB=       .83
      GAMC=       -.999
      CHIA=       -.236
      CHIB=       -.144
      CHIC=       .049
      GO TO 180
   70 IF(FNSTR1-3.) 75,85,80
   75 GA=         1.353
      GB=         -.708
      GC=         0.
```

```
      GAMA=     1.667
      GAMB=     0.
      GAMC=     0.
      CHIA=     -.339
      CHIB=     .022*(FNSTR1**2)
      CHIC=     0.
      GO TO 180
   80 IF(FNSTR1-6.) 85,90,90
   85 GA=       1.185
      GB=       .084
      GC=       -.864
      GAMA=     1.667
      GAMB=     0.
      GAMC=     0.
      CHIA=     -.216
      CHIB=     -.171
      CHIC=     0.
      GO TO 180
   90 GA=       1.081
      GB=       1.356
      GC=       -4.752
      GAMA=     1.667
      GAMB=     0.
      GAMC=     0.
      CHIA=     -.216
      CHIB=     -.171
      CHIC=     0.
      GO TO 180
   95 ALPHA=    .32
      BETA=     .0535
      IF(FNSTR1.GE.3.) GO TO 125
      IF(FNSTR1.LT.1.) GO TO 999
      FJ=       5.*FNSTR1 -4.
      J2=       FJ
      J1=       J2+1
      DX=       FJ -FLOAT(J2)
      BETA=     DX*(TABB(J1)-TABB(J2)) +TABB(J2)
      IF(FNSTR1-2.) 115,120,120
  115 GA=       -8.392*SQRT(FNSTR1-1.)
      GB=       30.513*SQRT(FNSTR1-1.)
      GC=      -16.431*SQRT(FNSTR1-1.)
      GAMA=     2.636
      GAMB=     -3.351
      GAMC=     3.255
      CHIA=     -.4585
      CHIB=     1.3815
      CHIC=     -.273
      GO TO 180
  120 GA=       3.375
      GB=       -7.644
      GC=       12.816
      GAMA=     1.576
      GAMB=     0.
      GAMC=     0.
      CHIA=     -.409
      CHIB=     2.046
      CHIC=     -1.8
```

```
      GO TO 180
  125 IF(FNSTR1-6.) 130,135,135
  130 GA=         1.206
      GB=         3.342
      GC=         -.504
      GAMA=       1.596
      GAMB=       0.
      GAMC=       0.
      CHIA=       -.12
      CHIB=       .6
      CHIC=       0.
      GO TO 180
  135 GA=         1.
      GB=         5.754
      GC=         -7.56
      GAMA=       1.596
      GAMB=       0.
      GAMC=       0.
      CHIA=       -.12
      CHIB=       .6
      CHIC=       0.
      GO TO 180
  140 GO TO (999,145,999,160) ,LP
  145 ALPHA=      -.01
      BETA=       -.019
      IF(FNSTR1-6.) 150,155,155
  150 GA=         1.213
      GB=         -1.53
      GC=         -.2
      GAMA=       1.707
      GAMB=       0.
      GAMC=       0.
      CHIA=       -.247
      CHIB=       -.272
      CHIC=       0.
      GO TO 180
  155 GA=         1.127
      GB=         -.438
      GC=         -3.672
      GAMA=       1.707
      GAMB=       0.
      GAMC=       0.
      CHIA=       -.247
      CHIB=       -.272
      CHIC=       0.
      GO TO 180
  160 ALPHA=      .321
      BETA=       .106
      IF(FNSTR1-6.) 165,170,170
  165 GA=         1.307
      GB=         3.104
      GC=         5.28
      GAMA=       1.565
      GAMB=       0.
      GAMC=       0.
      CHIA=       -.117
      CHIB=       1.17
```

```
      CHIC=      0.
      GO TO 180
  170 GA=        1.04
      GB=        6.486
      GC=        -5.4
      GAMA=      1.565
      GAMB=      0.
      GAMC=      0.
      CHIA=      -.117
      CHIB=      1.17
      CHIC=      0.
      GO TO 180
  175 ALPHA=     -.39
      BETA=      .05
      GA=        1.691
      GB=        -8.622
      GC=        16.2
      GAMA=      1.921
      GAMB=      0.
      GAMC=      0.
      CHIA=      -.362
      CHIB=      .599
      CHIC=      -2.452
  180 CONTINUE
      FN2=       FNSTR1*FNSTR1
      G=         GA +GB/FNSTR1 +GC/FN2
      GAM=       GAMA +GAMB/FNSTR1 +GAMC/FN2
      CHI=       CHIA +CHIB/FNSTR1 +CHIC/FN2
      CHI2=      CHI +ALPHA*(E-1.)/(FNSTR1*E-1.) +BETA*(E-1.)/E
      PHI=       3.1415927*(DEF2-DEF1+CHI2)
      GBS=       G*G*(COS(PHI)**2)/(E**(2.*GAM))
      FN4=       FNSTR1**4
      FN=        NINT2-NINT1
      F4=        KION**4
      R=         FN4*GBS/F4
      IF(NINT2.LE.0) R= 2.*FLOAT(KC**2)*R/(FNSTR2**3)
      RK=        FKAPPA
      FM0=       MZERO1
      FM1=       MONE1
      IF(NINT2.GT.0) FM1= DELNU*THETA/13.595
      QUAN=      FM0*FM1*FN*RK
      RETURN
  999 CALL ERROR(14,0999)
      RETURN
      END
```

```
@I FOR HYD/A
      SUBROUTINE HYD(T,D,K,QUAN,R)
C
C          HYDROGENIC APPROXIMATION
C
      COMMON/GALC/L1,L2,I1,I2,LN1,LN2,NINT1,NINT2,MZERO1,MONE1,KC,KS,
     2            U1,U2,FNSTR1,FNSTR2,FKAPP,DEF1
      THETA=      T
      DELNU=      D
      KION=       K
      FM0=        MZERO1
      FM1=        MONE1
      TDEL=       THETA*DELNU
      FLN1=       LN1
      FLN2=       LN2
      FN=         (NINT2-NINT1)**4
      FN=         1./FN
      FKION=      KION
      R=          9.23787*(FKION**4)*FN*((13.595/TDEL)**4)/
     6               (FLN1*FLN1*(FNSTR1**3))
      QUAN=       FM0*TDEL*FLOAT(NINT2-NINT1)*FKAPP*R/13.595
      IF(NINT2.GT.0) GO TO 10
      R=          2.*(FKION**2)*R/(FNSTR2**3)
      QUAN=       FM0*FM1*FLOAT(NINT2-NINT1)*FKAPP*R
   10 CONTINUE
      RETURN
      END
```

```
WI FOR NLINES/A
      SUBROUTINE NLINES(K1,K2,K3,ANS)
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
      COMMON//
     2 DEF(12,5)      , DELE2(12,2,20), D1UK(12)       , D1UK1(12)     ,
     3 D2UK(12)       , D2UK1(12)     , EM(12,2,20)    , EPS(12,2,20,6),
     4 FMNK(12,10)    , G(12,2,20)    , GKMI(12,5,10)  , JMIN(12,2)    ,
     5 NI(12,20,6)    , NMIN(12,5)    , NSET(12,2)     , PHIK(12)      ,
     6 PK(12)         , PKI(12,20)    , POTENT(12)     , UK(12)        ,
     7 UK1(12)        , V(12)         , WKI(12,2,20)
      COMMON//
     2 AJAY  , AMASS , BETA  , BETA2 , BIGX  , CCL   , CGMESH, CHI   ,
     3 CL    , CONST1, CP    , CV    , DEDTAU, DELNU , D1EXUK, D2EXUK,
     4 D1UK2 , D2UK2 , ENERGY, ENTHLP, EPSB1 , EPSB2 , EPSCL , EPSCON,
     5 EPSEND, EPSION, EPST  , EPSTR , EPSWK , EXUK  , GAMMA , GAMMA2,
     6 GI    , KD    , KMAXIN, KMAX  , KMIN  , LASTIT, LNAMAS, LNGAMA,
     7 NP    , PRESHR, RHO   , SMLS  , SS    , SZERO , TAU   , TEMP  ,
     8 THETA , THETAR, THETA2, THETA3, UK2   , UMAX  , ZBAR  , ZSTAR
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C
C         NUMBER OF LINES
C
      COMMON/GALC/L1,L2,I1,I2,[illegible],LN2:NINT1,NINT2,MZERO1,MONE1,KC,KS,
     2          U1,U2,FNST1,FNSTR2,FKAPP,DEF1
      DIMENSION DI(6),PHI(6),TAB(7,7)
      REAL LNAMAS,LNGAMA
      DATA DI/2.,2.,4.,10.,14.,18./
      DATA PHI/.75,.75,3.75,6.75,12.75,[illegible]75/
      DATA TAB/0.,2*1.,4*0.,1.,2*0.,1.,3*0.,1.,2*0.,2.,4*0.,2.,2.,0.,
     2         3.,5*0.,3.,0.,3.,5*0.,3.,0.,1.,5*0.,1.,1./
      ERF(X)=   1. -1./((1. +X*(.278393 +X*(.230389 +X*(.972E-3
     2             +.078108*X))))**4)
      EX(Y)=    1./((1. +Y*(.2507213 +Y*(.0292732 +.38278E-2*Y)))**4)
      FLIN(P,Q,R)= (P**(R*R))*(2. -P**(2.*R+1.)) +5.3173616/Q*ERF(Q*R)
      KION=     K1
      ICON=     K2
      KT=       K3
      FM0=      MZERO1
      FM1=      MONE1
      IF(KT.GT.0) GO TO 30
      IF(KS.GT.1) GO TO 20
      GAM=      0.
      DO 10 ID1=1,NP
      Y1=       NI(KION,ICON,ID1)
      Y2=       DI(ID1)
      GAM=      GAM + Y1*(Y2-Y1)/(Y2-1.)*PHI(ID1)
   10 CONTINUE
      ASSIGN 11 TO M
      GO TO 100
   11 ASSIGN 12 TO M
      GO TO 110
   12 IP=       I1
      ASSIGN 13 TO M
      GO TO 120
   13 A41=      A4
      IP =      I2
      ASSIGN 14 TO M
```

```
      GO TO 120
   14 A42=      A4
      ASSIGN 15 TO M
      GO TO 130
   15 CONTINUE
      Y1=       NI(KION,ICON,I2)
      Y2=       DI(I2)
      FL=       (Y2-Y1)/((Y1+1.)*DI(I2)*DI(I1)*DI(I1))*
     2           A1*A3/(A41*A42)
      SN=       A6*DI(I1)*G(KION,1,ICON)
      GO TO 140
   20 ICON=     JMIN(KION,1)
      GAM=      0.
      DO 21 ID1=1,NP
      Y1=       NI(KION,ICON,ID1)
      Y2=       DI(ID1)
      GAM=      GAM +Y1*(Y2-Y1)/(Y2-1.)*PHI(ID1)
   21 CONTINUE
      ASSIGN 22 TO M
      GO TO 100
   22 GO TO 150
   23 FL=       A1/(DI(I1)*DI(I1)*A5)
      ASSIGN 24 TO M
      GO TO 135
   24 SN=       A6*DI(I1)*G(KION,1,ICON)
      GO TO 140
   30 IF(KT.GT.1) GO TO 50
      Y1=       NI(KION,ICON,I1)
      Y2=       DI(I1)
      GAM=      (Y1-1.)*(Y2-Y1+1.)/(Y2-1.)*PHI(I1)
      IF(Y1.EQ.0.) GAM= 0.
      DO 31 ID1=1,NP
      IF(ID1.EQ.I1) GO TO 31
      Y1=       NI(KION,ICON,ID1)
      Y2=       DI(ID1)
      GAM=      GAM + Y1*(Y2-Y1)/(Y2-1.)*PHI(ID1)
   31 CONTINUE
      IF(KS.GT.1) GO TO 40
      ASSIGN 32 TO M
      GO TO 100
   32 ASSIGN 33 TO M
      GO TO 105
   33 ASSIGN 34 TO M
      GO TO 110
   34 IP=       I1
      ASSIGN 35 TO M
      GO TO 120
   35 A41=      A4
      IP=       I2
      ASSIGN 36 TO M
      GO TO 120
   36 A42=      A4
      Y11=      NI(KION,ICON,I1)
      Y21=      DI(I1)
      Y12=      NI(KION,ICON,I2)
      Y22=      DI(I2)
      FL=       (Y21 -Y11 +1.)*(Y22 -Y12)*A1*A3/(Y11*(Y12 +1.)*
```

```
     2              Y22*Y21*A41*A42)
       SN=          A2*Y11/(Y21-Y11+1.)*G(KION,1,ICON)
       GO TO 140
    40 ASSIGN 41 TO M
       GO TO 100
    41 ASSIGN 42 TO M
       GO TO 105
    42 IP=          I1
       ASSIGN 43 TO M
       GO TO 120
    43 Y1=          NI(KION,ICON,I1)
       Y2=          DI(I1)
       FL=          (Y2 -Y1 +1.)*A1/(Y1*A4)
       SN=          A2*Y1/(Y2-Y1+1.)*G(KION,1,ICON)
       GO TO 140
    50 ICON=        JMIN(KION,1)
       ID3=         0
       DO 53 ID1=1,NP
       EPSJ=        EPS(KION,1,ICON,ID1)
       IF(EPSJ.EQ.0.) GO TO 53
       IF(ID3.EQ.0) ID3= ID1
       IF(EPSJ.GT.EPS(KION,1,ICON,ID3)) ID3= ID1
    53 CONTINUE
       SAVEI=       I1
       I1=          ID3
       Y11=         NI(KION,ICON,I1)
       Y21=         DI(I1)
       GAM=         (Y11-1.)*(Y21-Y11+1.)/(Y21-1.)*PHI(I1)
       IF(Y11.EQ.0.) GAM= 0.
       DO 51 ID1=1,NP
       IF(ID1.EQ.I1) GO TO 51
       Y1=          NI(KION,ICON,ID1)
       Y2=          DI(ID1)
       GAM=         GAM +Y1*(Y2-Y1)/(Y2-1.)*PHI(ID1)
    51 CONTINUE
       ASSIGN 52 TO M
       GO TO 105
    52 FL=          1.
       I1=          SAVEI
       SN=          A2*Y11/(Y21-Y11+1.)*G(KION,1,ICON)
       GO TO 140
   100 A1=          0.
       DO 101 ID1=1,NP
       Y1=          NI(KION,ICON,ID1)
       Y2=          DI(ID1)
       A1=          A1+ Y1*(Y2-Y1)/(Y2-1.)*PHI(ID1)
   101 CONTINUE
       A1=          .785398*(SQRT(4.*A1+1.)-1.) +1.
       A1=          1./A1
       GO TO M,(11,22,32,41)
   105 A2=          0.
       Y1=          NI(KION,ICON,I1)
       IF(Y1.EQ.0.) GO TO 107
       Y2=          DI(I1)
       A2=          (Y1-1.)*(Y2-Y1+1.)/(Y2-1.)*PHI(I1)
   107 DO 106 ID1=1,NP
       IF(ID1.EQ.I1) GO TO 106
```

```
      Y1=       NI(KION,ICON,ID1)
      Y2=       DI(ID1)
      A2=       A2 +Y1*(Y2-Y1)/(Y2-1.)*PHI(ID1)
  106 CONTINUE
      A2=       .785398*(SQRT(4.*A2+1.)-1.) +1.
      A2=       1./A2
      GO TO M,(33,42,52)
  110 A3=       0.
      Y1=       NI(KION,ICON,I1)
      IF(Y1.EQ.0.) GO TO 112
      Y2=       DI(I1)
      A3=       (Y1-1.)*(Y2-Y1+1.)/(Y2-1.)*PHI(I1)
  112 Y1=       NI(KION,ICON,I2)
      Y2=       DI(I2)
      A3=       A3 +(Y1+1.)*(Y2-Y1-1.)/(Y2-1.)*PHI(I2)
      DO 111 ID1=1,NP
      IF(ID1.EQ.I1.OR.ID1.EQ.I2) GO TO 111
      Y1=       NI(KION,ICON,ID1)
      Y2=       DI(ID1)
      A3=       A3 + Y1*(Y2-Y1)/(Y2-1.)*PHI(ID1)
  111 CONTINUE
      A3=       .785398*(SQRT(4.*A3+1.)-1.)+1.
      A3=       1./A3
      GO TO M,(12,34)
  120 A4=       PHI(IP)
      Y1=       NI(KION,ICON,I1)
      IF(Y1.EQ.0.) GO TO 122
      Y2=       DI(I1)
      A4=       A4 +(Y1-1.)*(Y2-Y1+1.)/(Y2-1.)*PHI(I1)
  122 DO 121 ID1=1,NP
      IF(ID1.EQ.I1) GO TO 121
      Y1=       NI(KION,ICON,ID1)
      Y2=       DI(ID1)
      A4=       A4 +Y1*(Y2-Y1)/(Y2-1.)*PHI(ID1)
  121 CONTINUE
      A4=       .785398*(SQRT(4.*A4+1.)-1.) +1.
      A4=       1./A4
      GO TO M,(13,14,35,36,43)
  130 A5=       .5*PHI(I1)
      DO 131 ID1=1,NP
      Y1=       NI(KION,ICON,ID1)
      Y2=       DI(ID1)
      A5=       A5 +Y1*(Y2-Y1)/(Y2-1.)*PHI(ID1)
  131 CONTINUE
      A5=       .785398*(SQRT(4.*A5+1.)-1.) +1.
      A5=       1./A5
      GO TO 23
  135 A6=       PHI(I1)
      DO 137 ID1=1,NP
      Y1=       NI(KION,ICON,ID1)
      Y2=       DI(ID1)
      A6=       A6 +Y1*(Y2-Y1)/(Y2-1.)*PHI(ID1)
  137 CONTINUE
      A6=       .785398*(SQRT(4.*A6 +1.) -1.) +1.
      A6=       1./A6
      GO TO M,(15,24)
  140 CONTINUE
```

```
      IF(GAM.EQ.0.) GO TO 210
      B=          SQRT(4.*GAM+1.)-1.
      B=          1./(.196350*B*B)
      B1=         SQRT(B)
      D1=         EX(B)
      GO TO (150,154,158,162,168,172,174),I1
  150 IF(I2.EQ.3) GO TO 152
      FR=         .5
      SL=         FLIN(D1,B1,FR)
      GO TO 200
  152 FR=         .5
      SL=         FLIN(D1,B1,FR)
      GO TO 200
  154 IF(I2.EQ.4) GO TO 156
      FR=         .5
      SL=         FLIN(D1,B1,FR)
      GO TO 200
  156 FR=         .5
      SL=         2.*FLIN(D1,B1,FR)
      GO TO 200
  158 IF(I2.EQ.4) GO TO 160
      FR=         .5
      SL=         FLIN(D1,B1,FR)
      GO TO 200
  160 FR=         1.5
      SL=         2.*FLIN(D1,B1,FR)
      GO TO 200
  162 IF(I2.EQ.3) GO TO 164
      IF(I2.EQ.5) GO TO 166
      FR=         .5
      SL=         FLIN(D1,B1,FR)
      GO TO 200
  164 FR=         1.5
      SL=         2.*FLIN(D1,B1,FR)
      GO TO 200
  166 FR=         1.5
      SL=         FLIN(D1,B1,FR)
      FR=         2.5
      SL=         SL +2.*FLIN(D1,B1,FR)
      GO TO 200
  168 IF(I2.EQ.6) GO TO 170
      FR=         1.5
      SL=         FLIN(D1,B1,FR)
      FR=         2.5
      SL=         SL +2.*FLIN(D1,B1,FR)
      GO TO 200
  170 FR=         2.5
      SL=         FLIN(D1,B1,FR)
      FR=         3.5
      SL=         SL +2.*FLIN(D1,B1,FR)
      GO TO 200
  172 IF(I2.EQ.7) GO TO 174
      FR=         2.5
      SL=         FLIN(D1,B1,FR)
      FR=         3.5
      SL=         SL +2.*FLIN(D1,B1,FR)
      GO TO 200
```

```
  174 SL=       1.
  200 CONTINUE
      ANS=      CL*FM0*FM1*SL*FL*SN
      ANS=      AMAX1(ANS,FM0*FM1)
      RETURN
  210 SL=       TAB(I1,I2)
      GO TO 200
      END



@I FOR HF/A
      FUNCTION HF(N,A1,X1,H1)
C
C          J. C. STEWART APPROXIMATION FOR THE VOIGT FUNCTION
C
      DIMENSION U1(26),U2(26)
      DATA U1/.34737,.33937,.31665,.28270,.24227,.20023,.16059,.12596,
     2 .097503,.075200,.058314,.045802,.036610,.029837,.024765,.020946,
     3 .017969,.015611,.013708,.012147,.010847,.0097510,.0088179,
     4 .0080158,.0073207,.0067140/
      DATA U2/0.,-.078754,-.14505,-.18988,-.20977,-.10684,-.18712,
     2 -.15610,-.12654,-.097220,-.072640,-.053481,-.039265,-.029098,
     3 -.021898,-.016813,-.013184,-.010546,-.0085881,-.0071019,-.005951,
     4 -.0050435,-.0043167,-.0037265,-.0032415,-.0028848/
      EX(Y)=    1./(1. +Y*(.2507213 +Y*(.292732E-1 +.38278E-2*Y)))**4
      N1=       N
      A=        A1
      X=        X1
      H=        H1
      IF(N1.EQ.0) GO TO 30
      IF(A.GE.5.) GO TO 40
      IF(X.GT.5.) GO TO 10
      I1=       5.*X +1.
      FI=       .2*FLOAT(I1-1)
      I2=       I1 +1
      UAX1=     5.*(X -FI)*(U1(I2) -U1(I1)) +U1(I1)
      GO TO 20
   10 UAX1=     A/(3.1415927*X*X)
   20 H2X1=     1.772454*UAX1
      H0X1=     0.
      IF(X.LE.4.) H0X1= EX(X*X)
      BX1=      2.*(H2X1/(1. -.886277*H2X1) -H0X1)
      HAX1=     (H0X1 +A*BX1)/(1. +1.772454*A*(H0X1 +A*BX1))
      HF=       HAX1/H
      RETURN
   30 HF=       1./(1. +X*X)
      RETURN
   40 HF=       .56418958*A/(H*(A*A +X*X))
      RETURN
      END
```

```
@I FOR TF/A
      FUNCTION TF(T,F,H1,H2)
C
C          TRANSMISSION FUNCTION
C
      TBAR=      T
      FLINE=     F
      HBAR1=     H1
      HBAR2=     H2
      TF=        0.
      IF(FLINE.GT.10.) GO TO 30
      ARG1=      (1. -TBAR*HBAR1)**FLINE
      IF(ARG1.LT.1.E-3) RETURN
      TF=        1.
      ARG2=      (1. -TBAR*HBAR2)**FLINE
   10 IF((1.-ARG2).LT.1.E-3) RETURN
   20 TF=        (ARG1-ARG2)/(ALOG(ARG1/ARG2))
      RETURN
   30 ARG1=      EXP(-FLINE*TBAR*HBAR1)
      IF(ARG1.LT.1.E-3) RETURN
      TF=        1.
      ARG2=      EXP(-FLINE*TBAR*HBAR2)
      GO TO 10
      END


@I FOR ERROR/A
      SUBROUTINE ERROR(A)
C
C         A= XX.YYYY
C         XX INDICATES ROUTINE
C         YYYY INDICATES STATEMENT NUMBER
C         LIES =  1
C         OPAC =  2
C         BD   =  3
C         BS   =  4
C
      WRITE(6,10) A
   10 FORMAT(1H0,2X,7HERROR= ,F8.4)
      CALL DUMP
      RETURN
      END
```

REFERENCES

1. Judd, B. R., "Low-Lying Levels in Certain Actinide Atoms," Phys. Rev. 125, 613 (1962).
2. Gurvich, L. V., and V. S. Yugman, "Calculation of the Thermodynamic Properties of Gaseous Uranium and Plutonium and Their Ions up to 20,000°K," in Thermodynamics with Emphasis on Nuclear Materials and Atomic Transport in Solids, Vol. 2, p. 613, International Atomic Energy Agency, Vienna, 1966.
3. Krascella, N. L., "Theoretical Investigation of the Absorptive Properties of Small Particles and Heavy-Atom Gases," National Aeronautics and Space Administration Report NASA-CR-693, United Aircraft Corporation, 1967.
4. Cromer, D. T., D. Liberman, and J. T. Waber, Los Alamos Scientific Laboratory, private communication.
5. Sandström, A. E., "Experimental Methods of X-ray Spectroscopy," in Handbuch der Physik, Vol. XXX, p. 78, Springer-Verlag, Berlin, 1957.
6. Bearden, J. A., and A. F. Burr, Atomic Energy Levels (NYO-2543-1), U.S. Atomic Energy Commission, Division of Technical Information, Oak Ridge, Tennessee, 1965.
7. Herman, F., and S. Skillman, Atomic Structure Calculations, p. 313, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1963.
8. Cowan, R. D., et al., "Statistical Approximation for Exchange in Self-Consistent-Field Calculations of the Ground State of Neutral Argon," Phys. Rev. 144, 5 (1966).

9. Stewart, J. C., and M. Rotenberg, "Wave Functions and Transition Probabilities in Scaled Thomas-Fermi Ion Potentials," Phys. Rev. 140, A1508 (1965).

10. Rose, M. E., Relativistic Electron Theory, p. 222, John Wiley and Sons, Inc., New York, 1961.

11. Bethe, H. A., Intermediate Quantum Mechanics, W. A. Benjamin, Inc., New York, 1964.

12. Moskowski, S. A., Progr. Theoret. Phys. (Kyoto) 28, 1 (1962).

13. Mann, J. B., "Ionization of U, UO, and UO_2 by Electron Impact," J. Chem. Phys. 40, 1632 (1964).

14. Stewart, J. C., and K. D. Pyatt, Jr., "Lowering of Ionization Potentials in Plasmas," Astrophys. J. 144, 1203 (1966).

15. Münster, A., Statistische Thermodynamik, p. 765 ff, Springer-Verlag, Berlin, 1956.

15a. Landau, L. D. and E. M. Lifshitz, Statistical Physics, p. 70, Addison-Wesley Publishing Co., Reading, Mass., 1958.

16. Parks, D. E., and K. D. Pyatt, Jr., to be published.

17. Goody, R. M., Atmospheric Radiation. I. Theoretical Basis, Chap. 4, Oxford at the Clarendon Press, 1964.

18. Penner, S. S., Quantitative Moelcular Spectroscopy and Gas Emissivites, Addison-Wesley Publishing Co., Reading, Mass., 1959.

19. Stewart, J. C., "Integrated Absorptivity of Gaussian Clusters of Lorentz Lines," J. Quant. Spectr. Radiative Transfer 5, 489 (1965).

20. Hummer, D. G., "The Voigt Function: An Eight-Significant-Figure Table and Generating Procedure," Joint Institute for Laboratory Astrophysics Report JILA 24, University of Colorado, November 1964.

21. Brueckner, K. A., et al., "Study of the Recombination Phenomena Associated with a High Altitude Nuclear Explosion" (U), Air Force Special Weapons Center Report AFSWC-TDR-62-23 (GD-AE62-0389), March 1962. (Secret/Restricted Data)

22. Stewart, J. C., "Optical Properties of Uranium; Final Report" (U), Air Force Special Weapons Center Report AFSWC-TDR-62-143 (GA-3708), Vol. I, February 1963. (Secret/Restricted Data)

23. Stewart, J. C., and K. D. Pyatt, Jr., "Theoretical Studies of Optical Properties; Photon Absorption Coefficients, Opacities, and Equations of State of Light Elements, Including the Effect of Lines," Air Force Special Weapons Center Report AFSWC-TR-61-71 (GA-2528), Vol. I, September 1961.

24. Meggers, W. F., C. H. Corliss, and B. F. Scribner, Tables of Spectral Line Intensities, NBS Monograph 32, Parts I and II, U.S. Govt. Printing Office, 1961; and C. H. Corliss and W. R. Bozman, Experimental Transition Probabilities for Spectral Lines of Seventy Elements Derived from the NBS Tables of Spectral-Line Intensities, NBS Monograph 53, U.S. Govt. Printing Office, 1962.

25. Patch, R. W., NASA Lewis Research Center, Cleveland, Ohio, private communication, 1967.

26. Patch, R. W., NASA Lewis Research Center, Cleveland, Ohio, private communication, 1967.

27. Bates, D. R., and A. Damgaard, "The Calculation of the Absolute Strengths of Spectral Lines," Phil. Trans. Roy. Soc. London A242, 101 (1949).

28. Burgess, A., and M. F. Seaton, "A General Formula for the Calculation of Atomic Photo-Ionization Cross Sections," Monthly Notices Roy. Astron. Soc. 120, 121 (1960).

29. Griem, H. R., Plasma Spectroscopy, McGraw-Hill Book Co., New York, 1964.

30. Stewart, J. C., and D. E. Parks, to be published.

31. Araki, K., "Numerical Table of the Integral Expressing the Amount of Absorption or Emission of the Spectral Lines," Publ. Astron. Soc. Japan 6, 109 (1954).

32. Bond, J. W., Jr., K. M. Watson, and J. A. Welch, Atomic Theory of Gas Dynamics, p. 372, Addison-Wesley Publishing Co., Reading, Mass., 1965.

33. Raizer, Yu. P., "Simple Method for Computing the Mean Range of Radiation in Ionized Gases at High Temperatures," Sov. Phys. JETP 10, 769 (1960).