STEADY STATE RADIATIVE COOLING
RATES FOR LOW-DENSITY HIGH-
TEMPERATURE PLASMAS

BY

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**PLASMA PHYSICS
LABORATORY**

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Steady State Radiative Cooling Rates
For Low-Density High-Temperature Plasmas

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Steady-state radiative cooling rates, average charge states $\langle Z \rangle$, and mean square charge states $\langle Z^2 \rangle$ for 47 elements with atomic number Z ranging from 2 to 92 have been calculated for low-density ($n_e < 10^{16}$ electrons/cm³), high-temperature ($T = 0.002 \rightarrow 100$ keV) plasmas. The 47 elements spanning the periodic table include many materials of interest to controlled thermonuclear fusion research. The results for the radiation rates and charge states are presented graphically versus plasma temperature and in the form of least squares polynomial fits.

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INTRODUCTION

The radiation rates and charge states of atoms in high-temperature ($0.002 \rightarrow 100$ keV) and low-density ($\leq 10^{16} \text{ cm}^{-3}$) plasmas are of great interest to both the controlled fusion and astrophysical communities. Impurity ions of elements other than hydrogen are a serious problem in confined plasmas. In present tokamak experiments, impurity line radiation is a significant energy loss which cools the plasma.¹⁻⁵ In addition, these radiation rates are important in the study of astrophysical plasmas such as the solar corona.⁶

Low-density plasmas are transparent to their own radiation. Consequently, a "coronal equilibrium" results when the electron collisional ionization rate is exactly balanced by the total recombination rate. In general, for partially stripped ions dielectronic recombination dominates radiative recombination. In coronal equilibrium, radiation results from bremsstrahlung, radiative recombination, and $\Delta n = 0$ and $\Delta n \neq 0$ line transitions following electron collisional excitation, dielectronic recombination, and radiative recombination.

We have computed the steady-state ("coronal equilibrium") radiation, charge state $\langle Z \rangle$, and mean square charge state $\langle Z^2 \rangle$ as functions of the electron temperature ($0.002 \text{ keV} \leq T_e \leq 100 \text{ keV}$) for 47 elements ($Z = 2 \rightarrow 92$) in a low-density ($n_e \leq 10^{16}$) hydrogen plasma. Due to the uncertainties and complexities of the atomic physics, previous work has been limited to low- and moderate- Z elements.⁷⁻⁹ For $Z > 26$ earlier calculations of the

radiation rates consist primarily of order of magnitude¹⁰ estimates such as:

$$P_z = (10^{-25} + 10^{-26}) n_e n_z \text{ Watts/cm}^3,$$

calculations for highly stripped ions for $T_e \geq 10 \text{ keV}$,¹¹ and calculations of the radiation for molybdenum for $0.4 \text{ keV} \leq T_e \leq 40 \text{ keV}$ by the TFR group.⁹

Our results for steady-state emission show excellent agreement with previous calculations.⁷⁻⁹ Comparisons are shown in the figures. In addition, experimental measurements of the tungsten radiation on the ORMAK tokamak at Oak Ridge are consistent with our calculations for $T_e \sim 1 \text{ keV}$.¹²

An "average ion" model^{13,14,15} is employed in our calculation which permits, in principle, the simple treatment of elements with arbitrary Z . A description of the model and a useful summary of the rate coefficients for the important atomic processes are given in Appendices A and B.

The rate coefficients are, in general, uncertain by factors of 2 to 4. These uncertainties are particularly severe for high- Z materials for $T_e < 1 \text{ keV}$. Consequently, the results for the radiation rates can be expected to have the same level of accuracy. The effects of arbitrarily changing the dielectronic recombination and collisional ionization rates by factors of 2 are illustrated in Appendix C.

EXPLANATION OF GRAPHS

There are two graphs for each element. The cooling rate (ergs per free electron per ion per second) and average atomic charge are plotted as a function of electron temperature. For a number of elements, points from other calculations have been plotted for comparison.

COOLING RATE
(ergs-cm ³ /sec)	- This is the cooling rate per free electron per ion. The energy loss rate in ergs/(cm ³ sec) can be found by multiplying the cooling rate by the electron density and ion density.
T_e (keV)	- The electron temperature measured in kiloelectron volts.
<Z>	- The average charge state of the ion at a given temperature. It is defined as
$\langle Z \rangle = \sum_i Z_i n_i$ where n_i is the fraction of the ions in charge state i with charge Z_i .
POLYNOMIAL FIT	- The values for the polynomial fits to the cooling rates and average charge states are plotted.

- AVERAGE ION MODEL - The value of the cooling rate or charge state computed using the average ion model described in the appendices and reference (1).
- TARTER - Radiation rate calculation by Tarter.⁷
- MERTS et al. - Radiation rate calculation by Merts et al.⁸
- TFR - Radiation rate calculation by TFR group.⁹
- GERVIDS AND KOGAN - Radiation rate calculation by Gervids and Kogan.¹¹

EXPLANATION OF TABLES

Coefficients for polynomial least squares fits for the cooling rate, average charge, and mean square charge as functions of electron temperature are presented for each element. The curves were fitted separately in three or more temperature intervals. The temperature range spanned by the fits varies for different elements, generally decreasing with Z .

COOLING RATE - The cooling rate is given by:

$$\log_{10} L_z = \sum_{i=0}^5 A(i) \{ \log_{10} [T_e (\text{keV})] \}^i$$

where the $A(i)$ are drawn from the appropriate temperature interval. The radiative loss rate P_z in ergs/(cm³ sec) can be computed as:

$$P_z = n_e n_z L_z \quad \text{where}$$

n_e is the electron density in particles/cm³, n_z is the number density of element Z in ions/cm³, and L_z is computed from the polynomial fit.

AVERAGE Z

- The average charge state is computed as

$$\langle Z \rangle = \sum_{i=0}^5 B(i) [\log_{10} T_e (\text{keV})]^i$$

where the $B(i)$ are taken from the AVERAGE Z table for the appropriate temperature interval.

AVERAGE Z**2

- The average of the charge state squared is computed as

$$\langle Z^2 \rangle = \sum_{i=0}^5 C(i) [\log_{10} T_e (\text{keV})]^i$$

where the $C(i)$ are taken from the AVERAGE Z**2 table and from the appropriate temperature interval.

TMIN

- The lower bound of the electron temperature interval in keV . The smallest TMIN for each element is the limit of accuracy of our model.

TMAX

- The upper bound of the electron temperature interval in keV .

A(i),B(i),C(i)

- The coefficients in the polynomial fits for the cooling rate, $\langle Z \rangle$ and $\langle Z^2 \rangle$ respectively. There is a separate set of coefficients for each temperature interval, for each quantity L_z , $\langle Z \rangle$, and $\langle Z^2 \rangle$ and for each element.

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TABLE OF ELEMENTS

<u>Element</u>	<u>Symbol</u>	<u>Z</u>	<u>A</u>
1. Helium	He	2	4
2. Lithium	Li	3	7
3. Beryllium	Be	4	9
4. Boron	B	5	11
5. Carbon	C	6	12
6. Nitrogen	N	7	14
7. Oxygen	O	8	16
8. Fluorine	F	9	19
9. Neon	Ne	10	20
10. Sodium	Na	11	23
11. Magnesium	Mg	12	24
12. Aluminum	Al	13	27
13. Silicon	Si	14	28
14. Sulfur	S	16	32
15. Argon	Ar	18	40
16. Potassium	K	19	31
17. Calcium	Ca	20	40
18. Scandium	Sc	21	45
19. Titanium	Ti	22	48
20. Vanadium	V	23	51
21. Chromium	Cr	24	52
22. Iron	Fe	26	56

23.	Nickel	Ni	28	59
24.	Copper	Cu	29	64
25.	Zinc	Zn	30	65
26.	Arsenic	As	33	75
27.	Krypton	Kr	36	84
28.	Rubidium	Rb	37	86
29.	Zirconium	Zr	40	91
30.	Niobium	Nb	41	93
31.	Molybdenum	Mo	42	96
32.	Rhodium	Rh	45	103
33.	Silver	Ag	47	108
34.	Tin	Sn	50	119
35.	Xenon	Xe	54	131
36.	Cesium	Cs	55	133
37.	Barium	Ba	56	137
38.	Gadolinium	Gd	64	157
39.	Tantalum	Ta	73	181
40.	Tungsten	W	74	184
41.	Iridium	Ir	77	192
42.	Gold	Au	79	197
43.	Mercury	Hg	80	201
44.	Bismuth	Bi	83	209
45.	Radon	Rn	86	222
46.	Thorium	Th	90	232
47.	Uranium	U	92	238

COOLING RATE

TMIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
2.000E-03	2.000E-02	1.441278E 02	2.940867E 02	1.761164E 02	3.387430E 01	-3.075936E 00	-1.204179E 00
2.000E-02	2.000E-01	-2.274210E 01	-7.402954E-01	-2.177691E 00	-2.426768E 00	-1.026211E 00	-1.798547E-01
2.000E-01	2.000E 00	-2.254156E 01	3.503190E-01	1.210755E-01	-1.171573E-01	8.237547E-02	4.361719E-02
2.000E 00	2.000E 01	-2.258311E 01	6.858961E-01	-8.628176E-01	1.205242E 00	-7.386310E-01	1.686530E-01
2.000E 01	1.000E 02	-1.730458E 01	-1.624615E 01	2.100786E 01	-1.312075E 01	4.069350E 00	-5.009445E-01

AVERAGE Z

TMIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
2.000E-03	2.000E-02	5.571877E 02	1.257036E 03	1.121313E 03	4.920918E 02	1.062075E 02	9.030433E 00
2.000E-02	2.000E-01	2.032214E 00	1.590993E-01	3.084694E-01	2.935222E-01	1.371194E-01	2.517108E-02
2.000E-01	2.000E 00	1.999998E 00	-2.256051E-03	-6.879341E-03	4.463397E-02	1.713971E-01	1.432871E-01
2.000E 00	2.000E 01	2.002555E 00	2.946035E-02	-1.940473E-01	3.847468E-01	-3.156306E-01	9.289020E-02
2.000E 01	1.000E 02	-8.533870E 00	3.349834E 01	-4.229025E 01	2.650716E 01	-8.252386E 00	1.021276E 00

AVERAGE Z**2

TMIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
2.000E-03	2.000E-02	3.065347E 03	7.069801E 03	6.456789E 03	2.913580E 03	6.494822E 02	5.725003E 01
2.000E-02	2.000E-01	3.944735E 00	-2.564220E-01	-4.606469E-01	-3.988258E-01	-1.654224E-01	-2.604372E-02
2.000E-01	2.000E 00	3.999997E 00	-4.512101E-03	-1.375868E-02	9.926791E-02	3.427945E-01	2.865742E-01
2.000E 00	2.000E 01	4.005111E 00	5.892070E-02	-3.880945E-01	7.694936E-01	-6.312613E-01	1.857803E-01
2.000E 01	1.000E 02	-1.706773E 01	6.699669E 01	-8.458052E 01	5.301434E 01	-1.650476E 01	2.042555E 00

COOLING RATE							
THIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
5.000E-03	2.000E-02	-4.543672E 03	-1.150663E 04	-1.168350E 04	-5.917050E 03	-1.494044E 03	-1.503462E 02
2.000E-02	2.000E-01	-1.796097E 01	2.087143E 01	4.050722E 01	3.814958E 01	1.796065E 01	3.306693E 00
2.000E-01	2.000E 00	-2.211676E 01	2.157176E-01	2.693194E-01	-1.821747E-01	1.258669E-01	5.528849E-02
2.000E 00	2.000E 01	-2.210228E 01	1.019465E-01	6.025088E-01	-6.152173E-01	3.192364E-01	-6.169601E-02
2.000E 01	1.000E 02	-2.294214E 01	2.788428E 00	-2.772527E 00	1.692546E 00	-5.110030E-01	6.115965E-02
AVERAGE Z							
THIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
5.000E-03	2.000E-02	1.685620E 03	4.414336E 03	4.604082E 03	2.383148E 03	6.115146E 02	6.221194E 01
2.000E-02	2.000E-01	7.022807E 00	2.015094E 01	3.971342E 01	3.850490E 01	1.837981E 01	3.459540E 00
2.000E-01	2.000E 00	2.999997E 00	-3.384077E-03	-1.031901E-02	6.695052E-02	2.570958E-01	2.149307E-01
2.000E 00	2.000E 01	3.003833E 00	4.419044E-02	-2.910708E-01	5.771199E-01	-4.734459E-01	1.393352E-01
2.000E 01	1.000E 02	-1.280132E 01	5.024911E 01	-6.343735E 01	3.976155E 01	-1.237893E 01	1.531958E 00
AVERAGE Z**2							
THIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
5.000E-03	2.000E-02	-9.796371E 03	-2.410687E 04	-2.358175E 04	-1.148758E 04	-2.790884E 03	-2.708086E 02
2.000E-02	2.000E-01	2.939053E 01	1.020208E 02	2.007971E 02	1.944201E 02	9.267812E 01	1.742148E 01
2.000E-01	2.000E 00	9.000010E 00	1.047221E-04	-1.091150E-03	-3.243924E-03	1.126405E-02	2.517026E-02
2.000E 00	2.000E 01	8.904881E 00	7.927524E-01	-2.452587E 00	3.562078E 00	-2.451677E 00	6.445498E-01
2.000E 01	1.000E 02	-3.840398E 01	1.507474E 02	-1.903120E 02	1.192858E 02	-3.713680E 01	4.595876E 00

COOLING RATE

THIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
2.000E-03	2.000E-02	-3.425149E 02	-9.471260E 02	-1.035776E 03	-5.382415E 02	-1.349198E 02	-1.319063E 01
2.000E-02	2.000E-01	-3.429832E 01	-5.804948E 01	-1.032570E 02	-8.853015E 01	-3.530521E 01	-5.134460E 00
2.000E-01	2.000E 00	-2.177747E 01	4.617764E-02	4.411196E-01	-2.972147E-01	4.526295E-02	1.266794E-01
2.000E 00	2.000E 01	-2.177388E 01	1.478620E-02	5.259617E-01	-3.816430E-01	1.583400E-01	-2.891062E-02
2.000E 01	1.000E 02	-2.031496E 01	-4.202600E 00	5.289472E 00	-3.002456E 00	8.528627E-01	-9.687936E-02

AVERAGE Z

THIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
2.000E-03	2.000E-02	8.918311E 02	2.032827E 03	1.848711E 03	8.366675E 02	1.884457E 02	1.690050E 01
2.000E-02	2.000E-01	-2.541364E 01	-1.431782E 02	-2.719536E 02	-2.512535E 02	-1.124468E 02	-1.936447E 01
2.000E-01	2.000E 00	3.999932E 00	-3.436566E-04	5.915359E-03	8.912116E-03	-5.773581E-02	-7.638556E-02
2.000E 00	2.000E 01	3.957725E 00	3.523344E-01	-1.090038E 00	1.583144E 00	-1.089634E 00	2.864666E-01
2.000E 01	1.000E 02	-1.706773E 01	6.699669E 01	-8.458052E 01	5.301434E 01	-1.650476E 01	2.042555E 00

AVERAGE Z**2

THIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
2.000E-03	2.000E-02	4.351227E 03	9.911984E 03	8.995520E 03	4.062035E 03	9.127285E 02	8.164786E 01
2.000E-02	2.000E-01	-2.231015E 02	-1.166895E 03	-2.224691E 03	-2.066543E 03	-9.323203E 02	-1.625384E 02
2.000E-01	2.000E 00	1.600011E 01	1.047221E-03	-1.091150E-02	-3.243924E-02	1.126404E-01	2.517025E-01
2.000E 00	2.000E 01	1.583090E 01	1.409336E 00	-4.360155E 00	6.332582E 00	-4.358538E 00	1.145865E 00
2.000E 01	1.000E 02	-6.827095E 01	2.679866E 02	-3.383220E 02	2.120574E 02	-6.601909E 01	8.170219E 00

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
2.000E-03	2.000E-02	-1.508695E 03	-3.512257E 03	-3.286123E 03	-1.520070E 03	-3.470698E 02	-3.127689E 01
2.000E-02	2.000E-01	-6.370160E 01	-2.156758E 02	-4.308101E 02	-6.222842E 02	-2.408412E 02	-3.687482E 01
2.000E-01	2.000E 00	-2.147374E 01	-1.565300E-01	6.181287E-01	-2.477378E-01	-1.460488E-01	-4.537644E-02
2.000E 00	2.000E 01	-2.147137E 01	-1.829426E-01	6.678447E-01	-3.864809E-01	1.165920E-01	-1.400226E-02
2.000E 01	1.000E 02	-2.446408E 01	9.264950E 00	-1.110684E 01	6.837004E 00	-2.465106E 00	2.458526E-01

AVERAGE Z

TMIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
2.000E-03	2.000E-02	-6.553740E 02	-1.623267E 03	-1.589362E 03	-7.718708E 02	-4.857526E 02	-1.769887E 01
2.000E-02	2.000E-01	6.451282E 01	2.724490E 02	4.793284E 02	4.026719E 02	1.406613E 02	2.444832E 01
2.000E-01	2.000E 00	4.989811E 00	3.108082E-03	-7.757094E-03	-1.790018E-02	2.413855E-02	8.827370E-02
2.000E 00	2.000E 01	4.947156E 00	4.404179E-01	-1.362548E 00	1.978931E 00	-1.262042E 00	3.580832E-01
2.000E 01	1.000E 02	-2.113466E 01	8.374586E 01	-1.057256E 02	6.626793E 01	-2.163095E 01	2.553192E 00

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
2.000E-03	2.000E-02	-3.918029E 03	-9.662773E 03	-9.445668E 03	-4.582238E 03	-1.102251E 03	-1.050699E 02
2.000E-02	2.000E-01	5.923069E 02	2.630333E 03	4.701859E 03	4.033034E 03	1.353765E 03	2.604971E 02
2.000E-01	2.000E 00	2.499400E 01	3.003360E-02	-6.665945E-02	-1.465625E-01	1.287450E-01	6.310347E-01
2.000E 00	2.000E 01	2.473578E 01	2.202289E 00	-6.812743E 00	9.894661E 00	-4.310216E 00	1.790416E 00
2.000E 01	1.000E 02	-1.066733E 02	4.187292E 02	-5.286282E 02	3.313396E 02	-1.031548E 02	1.276596E-01

THIN	THAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
3.000E-03	2.000E-02	1.965300E 03	4.572039E 03	9.159590E 03	1.871560E 03	4.173889E 02	3.699382E 01
2.000E-02	2.000E-01	7.467599E 01	4.549038E 02	8.372937E 02	7.402515E 02	3.147607E 02	5.164578E 01
2.000E-01	2.000E 00	-2.120151E 01	-3.668933E-01	7.295099E-01	-1.944827E-01	-1.263576E-01	-1.491027E-01
2.000E 00	2.000E 01	-2.121979E 01	-2.346986E-01	4.093794E-01	7.874598E-02	-1.841379E-01	5.590744E-02
2.000E 01	1.000E 02	-2.476796E 01	9.408181E 00	-9.657446E 00	4.999161E 00	-1.237382E 00	1.160610E-01

AVERAGE Z

THIN	THAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
3.000E-03	2.000E-02	2.093736E 03	5.153766E 03	5.042105E 03	2.445345E 03	5.879207E 02	5.609128E 01
2.000E-02	2.000E-01	7.286051E 00	4.506650E 01	1.595483E 02	2.112702E 02	1.186473E 02	2.400040E 01
2.000E-01	2.000E 00	5.998782E 00	6.808206E-03	-3.096242E-02	-4.794194E-02	1.374732E-01	5.157571E-01
2.000E 00	2.000E 01	5.988153E 00	7.335329E-02	-1.754858E-01	2.034126E-01	-1.145930E-01	2.517150E-02
2.000E 01	1.000E 02	-3.412166E 01	1.250454E 02	-1.550822E 02	9.568297E 01	-2.937297E 01	3.589667E 00

AVERAGE Z**2

THIN	THAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
3.000E-03	2.000E-02	1.5696C4E 04	3.872013E 04	3.793754E 04	1.842954E 04	4.438563E 03	4.241526E 02
2.000E-02	2.000E-01	-8.567197E-01	-1.867449E-02	4.249500E-02	1.072139E-03	7.377224E-02	1.646775E-02
2.000E-01	2.000E 00	3.598505E 01	7.432950E-02	-2.552972E-01	-4.325508E-01	8.446683E-01	4.719095E 00
2.000E 00	2.000E 01	3.588152E 01	7.335339E-01	-1.754860E 00	2.034127E 00	-1.145931E 00	2.517152E-01
2.000E 01	1.000E 02	-2.047300E 02	7.502727E 02	-9.304934E 02	5.740977E 02	-1.762379E 02	2.153801E 01

COOLING RATE

THIN	TPAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
4.000E-03	2.000E-02	-1.967182E 02	-2.429049E 02	-7.454123E 01	3.126366E 01	2.166881E 01	3.300054E 00
2.000E-02	2.000E-01	-3.615155E 01	-3.943802E 01	-5.564129E 00	5.140343E 01	4.369243E 01	1.027448E 01
2.000E-01	2.000E 00	-2.693912E 01	-5.577397E-01	7.664689E-01	-2.610450E-01	3.464473E-01	6.723385E-01
2.000E 00	2.000E 01	-2.093039E 01	-6.511905E-01	1.146777E 00	-7.390625E-01	3.042676E-01	-6.024562E-02
2.000E 01	1.000E 02	-9.452522E 00	-3.583144E 01	4.386446E 01	-2.639331E 01	7.890268E 00	-9.366682E-01

AVERAGE Z

THIN	TPAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
4.000E-03	2.000E-02	-1.425406E 03	-3.495241E 03	-3.387818E 03	-1.630856E 03	-3.906016E 02	-3.726025E 01
2.000E-02	2.000E-01	-9.716010E 01	-5.013284E 02	-9.236924E 02	-8.128213E 02	-3.450171E 02	-5.686606E 01
2.000E-01	2.000E 00	6.996839E 00	2.894720E-02	-1.461315E-01	-3.084425E-01	3.661025E-01	3.278392E 00
2.000E 00	2.000E 01	6.998960E 00	-1.413698E 02	5.354933E-02	-6.592083E-02	3.344116E-02	-5.855095E-03
2.000E 01	1.000E 02	-3.980861E 01	1.458863E 02	-1.809293E 02	1.116301E 02	-3.426848E 01	4.187945E 00

AVERAGE Z**2

THIN	TPAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
4.000E-03	2.000E-02	-1.261020E 04	-3.058316E 04	-2.932491E 04	-1.394448E 04	-3.294323E 03	-3.096372E 02
2.000E-02	2.000E-01	-1.104950E 03	-5.599063E 03	-1.038766E 04	-9.191168E 03	-3.919907E 03	-6.489084E 02
2.000E-01	2.000E 00	4.895448E 01	3.787494E-01	-1.658999E 00	-3.817921E 00	3.669310E 00	4.020796E 01
2.000E 00	2.000E 01	4.872458E 01	1.966527E 00	-5.559625E 00	7.447222E 00	-2.711787E 00	1.134187E 00
2.000E 01	1.000E 02	-2.786516E 02	1.021178E 03	-1.266473E 03	7.813916E 02	-2.398735E 02	2.931491E 01

COOLING RATE

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
5.000E-03	2.000E-02	6.52374E 02	1.835499E 03	1.984266E 03	1.059846E 03	2.800476E 02	2.933792E 01
2.000E-02	2.000E-01	-5.51511E 01	-1.543956E 02	-2.489920E 02	-1.808154E 02	-5.764175E 01	-6.149181E 00
2.000E-01	2.000E 00	-2.068816E 01	-7.482238E-01	7.39(959E-01	-6.721590E-01	1.338345E 00	3.734628E 00
2.000E 00	2.000E 01	-2.066766E 01	-9.555590E-01	1.467982E 00	-9.822488E-01	4.171964E-01	-8.244216E-02
2.000E 01	1.000E 02	-2.780602E 01	2.146056E 01	-2.665906E 01	1.670831E 01	-5.191943E 00	6.410295E-01

AVERAGE Z

TMIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
5.000E-03	2.000E-02	-6.925547E 02	-1.855696E 03	-1.945779E 03	-1.008933E 03	-2.595559E 02	-2.652684E 01
2.000E-02	2.000E-01	7.888724E 01	2.975798E 02	4.826680E 02	3.902529E 02	1.580097E 02	2.576297E 01
2.000E-01	2.000E 00	7.988502E 00	7.240993E-02	-2.076878E-01	-3.743362E-01	-5.941060E-02	6.700652E 00
2.000E 00	2.000E 01	7.999472E 00	-6.130971E-02	2.776589E-01	-4.691578E-01	3.456361E-01	-9.306943E-02
2.000E 01	1.000E 02	-4.549416E 01	1.667230E 02	-2.067711E 02	1.275741E 02	-3.916302E 01	4.786110E 00

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
5.000E-03	2.000E-02	1.351521E 04	3.356807E 04	3.352594E 04	1.677875E 04	4.201137E 03	4.206570E 02
2.000E-02	2.000E-01	1.025210E 03	4.031522E 03	6.512734E 03	5.228730E 03	2.094185E 03	3.362681E 02
2.000E-01	2.000E 00	6.382906E 01	1.028260E 00	-2.942861E 00	-4.414907E 00	-3.030759E 00	9.179918E 01
2.000E 00	2.000E 01	6.382700E 01	5.711127E-01	-8.064272E-01	5.989529E-01	-2.597781E-01	5.956155E-02
2.000E 01	1.000E 02	-3.639531E 02	1.333784E 03	-1.654169E 03	1.020593E 03	-3.133042E 02	3.828888E 01

COOLING RATE

THIN	TMAX	B (0)	A (1)	A (2)	A (3)	A (4)	A (5)
6.000E-03	2.000E-02	9.771138E 02	2.608143E 03	2.730338E 03	1.426168E 03	3.715237E 02	3.861789E 01
2.000E-02	2.000E-01	-5.355138E 01	-1.994465E 02	-3.879919E 02	-3.528638E 02	-1.500805E 02	-2.412274E 01
2.000E-01	2.000E 00	-2.344910E 01	-9.224362E-01	8.075891E-01	-9.429368E-01	9.734815E-01	6.783201E 00
2.000E 00	2.000E 01	-2.343091E 01	-1.093509E 00	1.314363E 00	-5.879604E-01	1.307366E-01	-9.586941E-03
2.000E 01	1.000E 02	-2.385060E 01	2.631718E-01	-4.309072E-01	5.229414E-01	-2.143155E-01	3.089496E-02

AVERAGE Z

THIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
6.000E-03	2.000E-02	-7.421824E 02	-2.019623E 03	-2.162802E 03	-1.150331E 03	-3.046519E 02	-3.215074E 01
2.000E-02	2.000E-01	-6.386971E 01	-3.366482E 02	-6.527300E 02	-6.169387E 02	-2.833491E 02	-5.034203E 01
2.000E-01	2.000E 00	8.355293E 00	4.373749E-01	8.158798E-01	4.381809E 00	-1.659180E 01	-1.875661E 01
2.000E 00	2.000E 01	8.365586E 00	1.599156E-01	-3.630949E-01	4.522901E-01	-2.887546E-01	7.298005E-02
2.000E 01	1.000E 02	-5.818250E 01	1.875682E 02	-2.326234E 02	1.435244E 02	-4.405946E 01	5.384501E 00

AVERAGE Z**2

THIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
6.000E-03	2.000E-02	7.302078E 03	1.981265E 04	2.003793E 04	1.016856E 04	2.582948E 03	2.624504E 02
2.000E-02	2.000E-01	-7.733225E 02	-4.087541E 03	-7.944789E 03	-7.530761E 03	-3.470708E 03	-6.192622E 02
2.000E-01	2.000E 00	8.324899E 01	7.237563E-01	1.351959E 01	7.488019E 01	-2.771304E 02	-3.255342E 02
2.000E 00	2.000E 01	8.359183E 01	1.209760E 00	-1.267471E 00	2.000901E-01	4.618301E-01	-2.132820E-01
2.000E 01	1.000E 02	1.537469E 02	-2.180769E 02	2.596108E 02	-1.535161E 02	4.511751E 01	-5.274630E 00

COOLING RATE

TMIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
8.000E-03	2.000E-02	6.767667E 01	1.613787E 02	1.104767E 02	3.198749E 01	3.143149E 00	0.0
2.000E-02	2.000E-01	-6.805016E 01	-2.580876E 02	-5.346855E 02	-5.284263E 02	-2.476333E 02	-4.425504E 01
2.000E-01	2.000E 00	-2.032685E 01	-1.141439E 00	1.428329E 00	1.089571E 00	-6.969904E 00	-3.701472E 00
2.000E 00	2.000E 01	-2.031988E 01	-1.100588E 00	8.377123E-01	1.707851E-01	-3.522400E-01	1.041226E-01
2.000E 01	1.000E 02	-2.064906E 01	8.835572E-02	-2.864026E-01	4.440143E-01	-1.881675E-01	2.719145E-02

AVERAGE Z

TMIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
8.000E-03	2.000E-02	2.387652E 02	4.883521E 02	3.869072E 02	1.375382E 02	1.832860E 01	0.0
2.000E-02	2.000E-01	8.903922E 01	3.633115E 02	6.246609E 02	5.124253E 02	2.001083E 02	3.002850E 01
2.000E-01	2.000E 00	9.987808E 00	1.596451E-01	1.874297E-01	1.282721E 01	-2.747952E 01	-5.420656E 01
2.000E 00	2.000E 01	9.945612E 00	1.735784E-01	-2.181054E-01	1.058969E-01	3.161577E-03	-1.221873E-02
2.000E 01	1.000E 02	1.727525E 01	-2.180943E 01	2.596320E 01	-1.535289E 01	4.512136E 00	-5.275090E-01

AVERAGE Z**2

TMIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
8.000E-03	2.000E-02	1.576306E 03	3.119044E 03	2.388611E 03	8.275959E 02	1.084601E 02	0.0
2.000E-02	2.000E-01	1.277075E 03	5.470219E 03	9.475078E 03	7.845254E 03	3.097987E 03	4.700874E 02
2.000E-01	2.000E 00	9.831466E 01	3.456344E 00	-1.472818E 00	2.278931E 02	-4.538059E 02	-9.353008E 02
2.000E 00	2.000E 01	9.882779E 01	4.606832E 00	-8.300309E 00	8.001087E 00	-3.963363E 00	7.899949E-01
2.000E 01	1.000E 02	1.166322E 02	-5.797516E 01	7.907664E 01	-5.296407E 01	1.745827E 01	-2.269032E 00

SODIUM

Z = 11

A = 23

COOLING RATE

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
2.000E-02	2.000E-01	4.972095E 01	3.325496E 02	4.958772E 02	3.839436E 02	1.426147E 02	2.054829E 01
2.000E-01	2.000E 00	-2.001915E 01	-1.357335E 00	1.928337E 00	5.892109E 00	-1.838034E 01	-2.695123E 01
2.000E 00	2.000E 01	-2.002353E 01	-1.372276E 00	3.447962E-01	8.591520E-01	-7.474481E-01	1.887613E-01
2.000E 01	1.000E 02	-1.875806E 01	-5.181138E 00	5.947265E 00	-3.258113E 00	9.112158E-01	-1.031343E-01

AVERAGE Z

TMIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
2.000E-02	2.000E-01	1.185629E 02	5.395745E 02	1.026774E 03	9.393440E 02	4.120452E 02	6.981134E 01
2.000E-01	2.000E 00	1.088373E 01	1.286039E 00	-9.392968E 00	6.242580E 00	4.234340E 01	2.619530E 01
2.000E 00	2.000E 01	1.074116E 01	1.490458E 00	-3.652870E 00	4.30320E 00	-2.593946E 00	5.843369E-01
2.000E 01	1.000E 02	-6.255638E 01	2.292500E 02	-2.843174E 02	1.754188E 02	-5.385046E 01	6.581058E 00

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
2.000E-02	2.000E-01	1.855951E 03	8.781637E 03	1.679917E 04	1.546062E 04	6.825137E 03	1.162640E 03
2.000E-01	2.000E 00	1.185211E 02	2.712926E 01	-1.892224E 02	1.134188E 02	8.576636E 02	5.517483E 02
2.000E 00	2.000E 01	1.191660E 02	4.297462E 00	-2.709438E 00	-6.024196E-01	7.462482E-01	1.012714E-02
2.000E 01	1.000E 02	-6.881205E 02	2.521750E 03	-3.127492E 03	1.929606E 03	-5.923550E 02	7.239163E 01

MAGNESIUM $Z = 12$ $A = 24$

COOLING RATE

TMIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
2.000E-02	2.000E-01	5.905840E 01	3.799866E 02	6.972783E 02	6.095706E 02	2.571631E 02	4.226485E 01
2.000E-01	2.000E 00	-1.980008E 01	-1.257035E 00	-1.107867E 00	7.525729E 00	-1.294780E 00	-1.581264E 01
2.000E 00	2.000E 01	-1.981757E 01	-1.197740E 00	3.679842E-01	7.950444E-01	-6.447437E-01	1.502295E-01
2.000E 01	1.000E 02	-1.935489E 01	-2.924080E 00	3.115597E 00	-1.537552E 00	3.985283E-01	-4.283342E-02

AVERAGE Z

TMIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
2.000E-02	2.000E-01	-5.595412E 01	-2.590764E 02	-3.769197E 02	-2.536908E 02	-8.110489E 01	-9.829114E 00
2.000E-01	2.000E 00	1.153306E 01	3.070464E 00	-1.080354E 01	-8.296850E 00	5.505794E 01	6.125957E 01
2.000E 00	2.000E 01	1.203677E 01	-1.231541E 00	4.580839E 00	-6.802271E 00	4.531434E 00	-1.124451E 00
2.000E 01	1.000E 02	-6.824332E 01	2.500909E 02	-3.101643E 02	1.913659E 02	-5.874596E 01	7.179336E 00

AVERAGE Z**2

TMIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
2.000E-02	2.000E-01	-1.233214E 03	-5.197168E 03	-7.712527E 03	-5.317176E 03	-1.739607E 03	-2.167465E 02
2.000E-01	2.000E 00	1.356009E 02	6.868874E 01	-2.335377E 02	-1.926880E 02	1.180448E 03	1.329080E 03
2.000E 00	2.000E 01	1.367338E 02	3.379668E 01	-7.020874E 01	7.588411E 01	-4.112114E 01	8.783031E 00
2.000E 01	1.000E 02	2.066029E 00	4.089683E 02	-4.699417E 02	2.692063E 02	-7.688493E 01	8.758493E 00

ALUMINUM Z= 13 A= 27

COOLING RATE							
THIN	TMAX	L(0)	A(1)	A(2)	A(3)	A(4)	A(5)
2.000E-02	2.000E-01	-3.381084E 01	-2.732027E 01	2.338917E 00	3.422838E 01	2.474341E 01	5.515182E 00
2.000E-01	2.000E 00	-1.962679E 01	-7.248600E-01	-4.642358E 00	3.857418E 00	2.237978E 01	1.128082E 01
2.000E 00	2.000E 01	-1.663408E 01	-1.253421E 00	2.956862E-01	7.900675E-01	-5.607464E-01	1.148299E-01
2.000E 01	1.000E 02	-1.645946E 01	-5.213205E 00	5.78E378E 00	-3.139066E 00	8.849636E-01	-1.023228E-01

AVERAGE 2							
THIN	TMAX	E(0)	B(1)	B(2)	B(3)	B(4)	B(5)
2.000E-02	2.000E-01	-9.545670E 01	-4.73E570E 02	-8.245569E 02	-6.857727E 02	-2.784800E 02	-4.440573E 01
2.000E-01	2.000E 00	1.21709CE 01	4.760634E 00	-4.886456E 00	-2.124281E 01	1.739662E 01	4.209613E 01
2.00CE 00	2.000E 01	1.213602E 01	4.904298E 00	-1.203375E 01	1.495193E 01	-9.156422E 00	2.188726E 00
2.000E 01	1.00CE 02	-7.392801E 01	2.709246E 02	-3.360029E 02	2.073080E 02	-6.363991E 01	7.777430E 00

AVERAGE 2**2							
THIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
2.000E-02	2.000E-01	-2.051939E 03	-1.000553E 04	-1.752648E 04	-1.465093E 04	-5.955637E 03	-9.486531E 02
2.000E-01	2.000E 00	1.486358E 02	1.142438E 02	-1.057264E 02	-5.077476E 02	3.544121E 02	9.415007E 02
2.00CE 00	2.00CE 01	1.557112E 02	5.605629E 01	-1.051888E 02	1.050793E 02	-5.444179E 01	1.150776E 01
2.000E 01	1.000E 02	-5.159673E 02	2.121785E 03	-2.610958E 03	1.595125E 03	-4.838423E 02	5.830344E 01

SILICON Z= 14 A= 28

COOLING RATE

THIN	THAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
2.000E-02	2.000E-01	-5.250519E 01	-1.346130E 02	-2.082753E 02	-1.591874E 02	-5.989162E 01	-8.684849E 00
2.000E-01	2.000E 00	-1.954323E 01	4.994805E-02	-5.726766E 00	-2.710884E 00	3.050185E 01	2.689966E 01
2.000E 00	2.000E 01	-1.948920E 01	-1.136748E 00	-1.380692E-01	1.188993E 00	-7.120734E-01	1.348753E-01
2.000E 01	1.000E 02	-1.911072E 01	-2.668604E 00	2.438409E 00	-1.009559E 00	2.216468E-01	-2.078048E-02

AVERAGE Z

THIN	THAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
2.000E-02	2.000E-01	8.735831E-01	-8.673969E 01	-1.999606E 02	-1.937568E 02	-8.935628E 01	-1.605388E 01
2.000E-01	2.000E 00	1.260379E 01	5.045491E 00	6.829281E 00	-2.125352E 01	-5.119473E 01	-2.315088E 01
2.000E 00	2.000E 01	1.275454E 01	6.071817E 00	-1.285437E 01	1.395267E 01	-7.549129E 00	1.608778E 00
2.000E 01	1.000E 02	-1.955942E-01	4.090355E 01	-4.700235E 01	2.692558E 01	-7.689982E 00	8.760275E-01

AVERAGE Z**2

THIN	THAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
2.000E-02	2.000E-01	2.784709E 01	-1.319758E 03	-3.341606E 03	-3.290719E 03	-1.487660E 03	-2.577454E 02
2.000E-01	2.000E 00	1.593683E 02	1.294214E 02	1.818863E 02	-5.322231E 02	-1.336745E 03	-6.509641E 02
2.000E 00	2.000E 01	1.673633E 02	1.291199E 02	-2.559338E 02	2.652183E 02	-1.397297E 02	2.949785E 01
2.000E 01	1.000E 02	3.620842E 02	-5.790220E 02	7.898784E 02	-5.291033E 02	1.744211E 02	-2.267099E 01

SULFUR

Z = 16

A = 32

COOLING RATE

THIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
3.000E-02	2.000E-01	7.478835E 00	1.233280E 02	2.267822E 02	1.971580E 02	7.961913E 01	1.188285E 01
2.000E-01	2.000E 00	-1.959431E 01	1.120700E 00	-6.119577E-01	-1.511319E 01	9.656386E 00	3.007945E 01
2.000E 00	2.000E 01	-1.939664E 01	-3.758002E-02	-2.733615E 03	3.834586E 00	-2.045880E 00	4.085203E-01
2.000E 01	1.000E 02	-1.948795E 01	-5.561492E-03	-8.844770E-01	8.673531E-01	-3.601739E-01	5.002120E-02

AVERAGE Z

THIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
3.000E-02	2.000E-01	1.478065E 02	6.550137E 02	1.261559E 03	1.215119E 03	5.747527E 02	1.061944E 02
2.000E-01	2.000E 00	1.399091E 01	1.655738E 00	-1.065580E 01	8.729357E 00	-3.824394E 01	-2.932738E 01
2.000E 00	2.000E 01	-1.306910E 01	1.251600E 01	-2.295264E 01	2.178799E 01	-1.048162E 01	2.019732E 00
2.000E 01	1.000E 02	-6.564059E 01	2.450840E 02	-2.923765E 02	1.732427E 02	-5.099164E 01	5.965722E 00

AVERAGE Z**2

THIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
3.000E-02	2.000E-01	2.088994E 03	3.942191E 03	1.655088E 04	1.558028E 04	7.282078E 03	1.338038E 03
2.000E-01	2.000E 00	-1.957418E 02	4.792966E 01	3.127610E 02	2.775198E 02	-1.087663E 03	-9.496191E 02
2.000E 00	2.000E 01	1.642715E 02	4.005506E 02	-7.539924E 02	7.361904E 02	-3.650266E 02	7.267825E 01
2.000E 01	1.000E 02	-1.007283E 03	-2.350099E 03	2.915165E 03	-1.794525E 03	5.485510E 02	-6.663963E 01

COOLING RATE

THIN	THAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
3.000E-02	2.000E-01	-1.053043E 01	-2.834287E 00	1.506902E 01	3.517177E 01	2.400122E 01	5.072723E 00
2.000E-01	2.000E 00	-1.965204E 01	-1.172763E-01	7.833220E 00	-6.351577E 00	-3.058849E 01	-1.528534E 01
2.000E 00	2.000E 01	-1.974883E 01	2.964839E 00	-8.829391E 00	9.791004E 00	-4.960018E 00	9.820032E-01
2.000E 01	1.000E 02	-2.117935E 01	5.191481E 00	-7.439717E 00	4.969023E 00	-1.553180E 00	1.877047E-01

AVERAGE Z

THIN	THAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
3.000E-02	2.000E-01	-6.351877E 01	-4.145188E 02	-8.502200E 02	-8.074783E 02	-3.621262E 02	-6.187830E 01
2.000E-01	2.000E 00	1.591067E 01	-7.886774E-01	2.878539E 01	3.361189E 01	-3.306891E 01	-7.162601E 01
2.000E 00	2.000E 01	1.296383E 01	1.833252E 01	-2.834795E 01	2.267165E 01	-9.219744E 00	1.507133E 00
2.000E 01	1.000E 02	-7.690005E 01	2.939922E 02	-3.551084E 02	2.133685E 02	-6.376566E 01	7.582572E 00

AVERAGE Z**2

THIN	THAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
3.000E-02	2.000E-01	-9.617104E 02	-6.478980E 03	-1.394668E 04	-1.372414E 04	-6.350906E 03	-1.120351E 03
2.000E-01	2.000E 00	2.534142E 02	-2.346306E 02	7.075633E 01	1.014115E 03	-7.342520E 02	-1.963298E 03
2.000E 00	2.000E 01	1.582535E 02	5.763311E 02	-8.295298E 02	5.954534E 02	-2.057947E 02	2.602888E 01
2.000E 01	1.000E 02	2.959939E 02	6.590942E 01	-7.358733E 01	4.647609E 01	-1.567553E 01	2.167101E 00

POTASSIUM $Z = 19$ $A = 31$

COOLING RATE

THIN	THAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
3.000E-02	2.000E-01	5.314929E 01	3.605864E 02	7.242861E 02	7.227720E 02	3.556333E 02	6.856114E 01
2.000E-01	2.000E 00	-1.958510E 01	-1.247590E 00	9.635968E 00	2.269679E 03	-4.021016E 01	-3.575417E 01
2.000E 00	2.000E 01	-2.005470E 01	4.846460E 00	-1.233299E 01	1.304019E 01	-6.497760E 00	1.278673E 00
2.000E 01	1.000E 02	-1.972728E 01	8.953001E-01	-2.042113E 00	1.563222E 00	-4.831363E-01	5.421992E-02

AVERAGE Z

THIN	THAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
3.000E-02	2.000E-01	2.872214E 01	-1.371293E 01	-1.875789E 02	-3.023074E 02	-1.844626E 02	-3.919647E 01
2.000E-01	2.000E 00	1.696857E 01	1.483019E-02	-5.457079E 00	3.058327E 01	-1.620343E 01	-6.193134E 01
2.000E 00	2.000E 01	1.414701E 01	1.199806E 01	-7.349702E 00	-5.086492E 00	7.419888E 00	-2.260574E 00
2.000E 01	1.000E 02	-4.11810E 00	6.796837E 01	-7.983821E 01	4.669469E 01	-1.357690E 01	1.568650E 00

AVERAGE Z**2

THIN	THAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
3.000E-02	2.000E-01	1.159235E 03	3.119937E 03	2.690640E 03	1.875711E 00	-9.190972E 02	-2.902529E 02
2.000E-01	2.000E 00	2.880354E 02	2.637594E 00	-1.879575E 02	9.061582E 02	-2.823303E 02	-1.738787E 03
2.000E 00	2.000E 01	1.896255E 02	4.090110E 02	-2.127012E 02	-2.384151E 02	2.955244E 02	-8.701749E 01
2.000E 01	1.000E 02	8.291567E 02	-1.434792E 03	1.723672E 03	-1.021455E 03	2.996453E 02	-3.488251E 01

CALCIUM Z= 20 A= 40

COOLING RATE

THIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
3.000E-02	2.000E-01	-7.649536E 01	-2.817832E 02	-5.278674E 02	-4.738796E 02	-2.036197E 02	-3.362292E 01
2.000E-01	2.000E 00	-1.943642E 01	-2.202074E 00	8.978452E 00	8.856277E 00	-4.001584E 01	-4.505820E 01
2.000E 00	2.000E 01	-2.089655E 01	9.596070E 00	-2.209296E 01	2.310663E 01	-1.171187E 01	2.356970E 00
2.000E 01	1.000E 02	-2.010780E 01	2.404658E 00	-3.953416E 00	2.727055E 00	-8.326892E-01	9.609270E-02

AVERAGE Z

THIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
3.000E-02	2.000E-01	-6.167589E 00	-1.400073E 02	-3.887622E 02	-4.804817E 02	-2.739529E 02	-5.829929E 01
2.000E-01	2.000E 00	1.798602E 01	1.441255E 00	-1.818689E 01	2.788094E 01	5.928369E 01	1.507056E 01
2.000E 00	2.000E 01	2.066919E 01	-2.711781E 01	9.034389E 01	-1.196802E 02	7.193733E 01	-1.634720E 01
2.000E 01	1.000E 02	6.594911E 01	-1.440557E 02	1.784182E 02	-1.094122E 02	3.326740E 01	-4.015639E 00

AVERAGE Z**2

THIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
3.000E-02	2.000E-01	1.625729E 02	-8.361431E 02	-3.837752E 03	-5.734059E 03	-3.614106E 03	-8.172859E 02
2.000E-01	2.000E 00	3.232957E 02	5.130704E 01	-6.094551E 02	8.134255E 02	2.224724E 03	8.278169E 02
2.000E 00	2.000E 01	4.283096E 02	-1.046929E 03	3.467602E 03	-4.587922E 03	2.759647E 03	-6.282830E 02
2.000E 01	1.000E 02	5.357544E 02	-4.962583E 02	6.657529E 02	-4.280183E 02	1.341810E 02	-1.654413E 01

SCANDIUM Z= 21 A= 45

COOLING RATE

TMIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
2.000E-02	2.000E-01	-3.758694E 01	-1.130825E 02	-2.400835E 02	-2.460911E 02	-1.185292E 02	-2.165903E 01
2.000E-01	2.000E 00	-1.922758E 01	-2.983667E 00	5.788243E 00	1.446065E 01	-2.243102E 01	-3.605351E 01
2.000E 00	2.000E 01	-2.085631E 01	8.626213E 00	-1.803065E 01	1.718071E 01	-7.971809E 00	1.483114E 00
2.000E 01	1.000E 02	-1.374122E 01	-1.629939E 01	1.819852E 01	-1.035079E 01	3.010462E 00	-3.534541E-01

AVERAGE Z

TMIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
2.000E-02	2.000E-01	1.500035E 02	6.557107E 02	1.196352E 03	1.051839E 03	4.447375E 02	7.286873E 01
2.000E-01	2.000E 00	1.884494E 01	3.934366E 00	-2.836484E 01	1.774383E 01	1.123195E 02	7.216382E 01
2.000E 00	2.000E 01	2.704558E 01	-6.457207E 01	1.821357E 02	-2.257938E 02	1.311246E 02	-2.921051E 01
2.000E 01	1.000E 02	5.099635E 00	4.933327E 01	-6.247444E 01	3.988538E 01	-1.275218E 01	1.627258E 00

AVERAGE Z**2

TMIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
2.000E-02	2.000E-01	2.931570E 03	1.330937E 04	2.440042E 04	2.157848E 04	9.183113E 03	1.512909E 03
2.000E-01	2.000E 00	3.551611E 02	1.417655E 02	-9.804771E 02	4.147202E 02	4.207078E 03	3.114042E 03
2.000E 00	2.000E 01	6.724409E 02	-2.494884E 03	7.020754E 03	-8.672379E 03	5.018617E 03	-1.114524E 03
2.000E 01	1.000E 02	1.091817E 02	3.870320E 02	-9.808699E 02	5.543164E 02	-1.589490E 02	1.844151E 01

TITANIUM Z= 22 A= 48

COOLING RATE

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
2.000E-02	2.000E-01	2.391331E 01	1.833595E 02	3.019617E 02	2.376019E 02	9.049792E 01	1.345090E 01
2.000E-01	2.000E 00	-1.899097E 01	-3.403261E 00	1.439830E 00	1.735576E 01	2.804832E-01	-1.943971E 01
2.000E 00	2.000E 01	-1.929037E 01	-3.260377E 00	1.454427E 01	-2.383997E 01	1.642804E 01	-4.084697E 00
2.000E 01	1.000E 02	-1.341780E 01	-1.675967E 01	1.843320E 01	-1.033234E 01	2.960530E 00	-3.423194E-01

AVERAGE Z

TMIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
2.000E-02	2.000E-01	7.222363E 01	3.198137E 02	6.487275E 02	6.246682E 02	2.837644E 02	4.928307E 01
2.000E-01	2.000E 00	1.945238E 01	7.359536E 00	-3.185284E 01	9.823505E-01	1.158896E 02	8.529936E 01
2.000E 00	2.000E 01	2.850867E 01	-6.440732E 01	1.697102E 02	-1.977441E 02	1.085692E 02	-2.299095E 01
2.000E 01	1.000E 02	-2.366887E 01	1.361008E 02	-1.625276E 02	9.680211E 01	-2.869588E 01	3.383613E 00

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
2.000E-02	2.000E-01	1.387805E 03	6.68877CE 03	1.379025E 04	1.349106E 04	6.223688E 03	1.094611E 03
2.000E-01	2.000E 00	3.793196E 02	2.711609E 02	-1.126145E 03	-2.464515E 02	4.480199E 03	3.913639E 03
2.000E 00	2.000E 01	7.469683E 02	-2.624861E 03	6.906609E 03	-8.029152E 03	4.400336E 03	-9.309294E 02
2.000E 01	1.000E 02	3.507414E 01	1.223517E 03	-1.382728E 03	7.984304E 02	-2.334778E 02	2.750656E 01

VANADIUM

Z = 23

A = 51

COOLING RATE

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
2.000E-02	2.000E-01	3.687357E 01	2.607222E 02	4.728840E 02	4.134180E 02	1.758225E 02	2.924307E 01
2.000E-01	2.000E 00	-1.875536E 01	-3.336187E 00	-3.515679E 00	1.543945E 01	2.698933E 01	8.739810E 00
2.000E 00	2.000E 01	-1.789319E 01	-1.323304E 01	4.055650E 01	-5.535688E 01	3.461508E 01	-8.129329E 00
2.000E 01	1.000E 02	-7.774825E 00	-3.356671E 01	3.861874E 01	-2.241156E 01	6.556648E 00	-7.682697E-01

AVERAGE Z

TMIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
2.000E-02	2.000E-01	-2.169506E 01	-1.124302E 02	-1.072995E 02	-1.034071E 01	2.558121E 01	8.405830E 00
2.000E-01	2.000E 00	1.984456E 01	1.165312E 01	-3.384995E 01	-2.939377E 01	1.305076E 02	1.416279E 02
2.000E 00	2.000E 01	2.329027E 01	-1.420115E 01	2.186555E 01	8.453312E-01	-1.576187E 01	6.522937E 00
2.000E 01	1.000E 02	1.268253E 02	-3.207415E 02	3.912087E 02	-2.361976E 02	7.070305E 01	-8.402188E 00

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
2.000E-02	2.000E-01	-6.429275E 02	-2.572983E 03	-2.239297E 03	2.210848E 02	9.248943E 02	2.731477E 02
2.000E-01	2.000E 00	3.951780E 02	4.357852E 02	-1.132127E 03	-1.303862E 03	-4.341715E 03	5.150230E 03
2.000E 00	2.000E 01	5.349314E 02	-5.721934E 02	8.224382E 02	2.018259E 02	-7.832712E 02	3.055291E 02
2.000E 01	1.000E 02	-2.796076E 02	2.251992E 03	-2.574478E 03	1.492329E 03	-4.355811E 02	5.100261E 01

COOLING RATE

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
2.000E-02	2.000E-01	-1.046617E 01	4.84776E 01	1.035314E 02	9.965564E 01	4.533922E 01	7.963568E 00
2.000E-01	2.000E 00	-1.856281E 01	-2.86142E 00	-7.078976E 00	1.040950E 01	4.279950E 01	2.955975E 01
2.000E 00	2.000E 01	-1.703891E 01	-1.819385E 01	5.078029E 01	-6.452573E 01	3.818620E 01	-8.587522E 00
2.000E 01	1.000E 02	-1.412390E 01	-1.399585E 01	1.491615E 01	-8.166685E 00	2.301365E 00	-2.624429E-01

AVERAGE Z

TMIN	TMAX	E (0)	B (1)	B (2)	B (3)	B (4)	B (5)
2.000E-02	2.000E-01	-7.697792E 01	-4.031421E 02	-6.778428E 02	-5.422778E 02	-2.129268E 02	-3.303242E 01
2.000E-01	2.000E 00	1.995401E 01	1.572642E 01	-2.605127E 01	-5.679381E 01	8.449048E 01	1.336010E 02
2.000E 00	2.000E 01	1.848369E 01	3.114391E 01	-1.073632E 02	1.691199E 02	-1.181783E 02	3.022896E 01
2.000E 01	1.000E 02	-3.757317E 01	1.854461E 02	-2.250167E 02	1.366963E 02	-4.145073E 01	5.011191E 00

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
2.000E-02	2.000E-01	-2.333009E 03	-1.131370E 04	-1.922350E 04	-1.551337E 04	-6.095250E 03	-9.413032E 02
2.000E-01	2.000E 00	4.005039E 02	5.985132E 02	-7.842603E 02	-2.277633E 03	2.089804E 03	4.153375E 03
2.000E 00	2.000E 01	3.298301E 02	1.382955E 03	-4.803656E 03	7.594379E 03	-5.313602E 03	1.359604E 03
2.000E 01	1.000E 02	1.045110E 03	-1.727755E 03	2.313882E 03	-1.479032E 03	4.599707E 02	-5.618463E 01

IRON Z = 26 A = 56

COOLING RATE

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
2.000E-02	2.000E-01	-2.75259E 01	-3.90822E 01	-6.465423E 01	-5.555048E 01	-2.405568E 01	-4.093160E 00
2.000E-01	2.000E 00	-1.834973E 01	-1.252028E 00	-7.533115E 00	-3.289693E 00	2.866739E 01	2.830249E 01
2.000E 00	2.000E 01	-1.671082E 01	-1.646143E 01	3.766238E 01	-3.944080E 01	1.918529E 01	-3.509238E 00
2.000E 01	1.000E 02	-2.453957E 01	1.795222E 01	-2.356360E 01	1.484503E 01	-4.542323E 00	5.477462E -01

AVERAGE Z

TMIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
2.000E-02	2.000E-01	8.778318E 00	-5.581412E 01	-1.225124E 02	-1.013985E 02	-3.914244E 01	-5.851445E 00
2.000E-01	2.000E 00	1.959496E 01	1.997852E 01	9.593373E 00	-7.609962E 01	-1.007190E 02	-1.184046E 01
2.000E 00	2.000E 01	1.478150E 01	6.945311E 01	-1.991202E 02	2.653804E 02	-1.631423E 02	3.770026E 01
2.000E 01	1.000E 02	2.122081E 01	6.891507E 00	-4.076853E 00	1.577171E 00	-5.139468E -01	8.934176E -02

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
2.000E-02	2.000E-01	-1.629057E 00	-2.038262E 03	-4.720863E 03	-4.299215E 03	-1.797781E 03	-2.879963E 02
2.000E-01	2.000E 00	3.885212E 02	7.909700E 02	6.077126E 02	-2.903589E 03	-5.163387E 03	-1.865747E 03
2.000E 00	2.000E 01	1.181937E 02	3.464816E 03	-9.953434E 03	1.328093E 04	-8.173660E 03	1.891447E 03
2.000E 01	1.000E 02	-3.243616E 02	2.476134E 03	-2.551817E 03	1.348646E 03	-3.619529E 02	3.921327E 01

NICKEL Z= 28 A= 59

COOLING RATE

TMIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
3.000E-02	2.000E-01	-1.233248E 01	3.253908E 01	6.790773E 01	6.529924E 01	2.973465E 01	5.271279E 00
2.000E-01	2.000E 00	-1.830482E 01	-3.319243E-03	-3.332313E 00	-1.112798E 01	1.053073E-01	9.448907E 00
2.000E 00	2.000E 01	-1.697678E 01	-9.495470E 00	1.109362E 01	4.045904E-02	-6.521934E 00	2.654915E 00
2.000E 01	1.000E 02	-2.864081E 01	2.999289E 01	-3.726082E 01	2.258060E 01	-6.716598E 00	7.911687E-01

AVERAGE Z

TMIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
3.000E-02	2.000E-01	1.032411E 01	-6.184296E 01	-1.600052E 02	-1.564106E 02	-7.153975E 01	-1.267768E 01
2.000E-01	2.000E 00	1.929729E 01	1.590131E 01	4.115131E 01	-2.440034E 01	-2.109272E 02	-1.651743E 02
2.000E 00	2.000E 01	1.746326E 01	4.985335E 01	-1.125172E 02	1.169296E 02	-5.367584E 01	8.534334E 00
2.000E 01	1.000E 02	-8.434801E 01	3.265640E 02	-3.836858E 02	2.261836E 02	-6.665651E 01	7.841199E 00

AVERAGE Z**2

TMIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
3.000E-02	2.000E-01	5.68427E 02	3.333879E 02	-1.011411E 03	-1.504321E 03	-7.744282E 02	-1.418581E 02
2.000E-01	2.000E 00	3.751799E 02	6.537412E 02	-1.820442E 03	-7.303191E 02	-8.668484E 03	-7.228750E 03
2.000E 00	2.000E 01	2.456799E 02	2.51565E 02	-5.659594E 03	5.820426E 03	-2.609690E 03	3.946589E 02
2.000E 01	1.000E 02	-5.465603E 02	3.217438E 03	-3.283618E 03	1.738274E 03	-4.714497E 02	5.196114E 01

COPEER Z= 29 A= 64

COOLING RATE

TMIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
3.000E-02	2.000E-01	-1.751314E 01	6.909913E 00	2.271756E 01	2.718317E 01	1.415977E 01	2.801611E 00
2.000E-01	2.000E 00	-1.830912E 01	2.274986E-01	-1.275432E 00	-1.123179E 01	-6.848201E 00	4.333373E 00
2.000E 00	2.000E 01	-1.695900E 01	-7.326308E 00	2.601280E 00	1.201293E 01	-1.377229E 01	4.259735E 00
2.000E 01	1.000E 02	-2.648274E 01	2.298584E 01	-2.815227E 01	1.675992E 01	-4.884827E 00	5.635291E-01

AVERAGE Z

TMIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
3.000E-02	2.000E-01	2.493200E 01	7.113712E 00	-3.587790E 01	-4.772021E 01	-2.497487E 01	-4.844240E 00
2.000E-01	2.000E 00	1.950127E 01	1.168801E 01	-4.453229E 01	1.535716E 01	-1.945137E 02	-1.927700E 02
2.000E 00	2.000E 01	1.696854E 01	4.323923E 01	-8.931979E 01	6.749509E 01	-1.527694E 01	-1.725679E 00
2.000E 01	1.000E 02	2.642157E 01	-8.491531E 00	2.149261E 01	-1.696663E 01	5.838782E 00	-7.561221E-01

AVERAGE Z**2

TMIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
3.000E-02	2.000E-01	7.115466E 02	1.000331E 03	9.565353E 01	-6.488293E 02	-4.635715E 02	-9.954163E 01
2.000E-01	2.000E 00	3.816694E 02	4.887107E 02	1.935704E 03	9.256245E 02	-7.466625E 03	-7.789199E 03
2.000E 00	2.000E 01	2.442491E 02	2.296728E 03	-3.906596E 03	2.502951E 03	-1.300864E 02	-2.573018E 02
2.000E 01	1.000E 02	-9.596125E 02	4.500422E 03	-4.749848E 03	2.596472E 03	-7.254873E 02	8.217462E 01

COOLING RATE

THIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
3.000E-02	2.000E-01	-2.383649E 01	-2.511417E 01	-3.889651E 01	-2.974194E 01	-1.135297E 01	-1.641334E 00
2.000E-01	2.000E 00	-1.831641E 01	2.348402E-01	5.838277E-01	-9.666894E 00	-1.170652E 01	-7.421595E-01
2.000E 00	2.000E 01	-1.711081E 01	-4.611918E 00	-5.473824E 00	2.132755E 01	-1.834232E 01	5.039056E 00
2.000E 01	1.000E 02	-2.305847E 01	1.205724E 01	-1.427137E 01	8.073050E 00	-2.201411E 00	2.355720E-01

AVERAGE Z

THIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
3.000E-02	2.000E-01	3.709377E 01	6.916623E 01	8.398711E 01	6.441956E 01	2.613870E 01	4.263496E 00
2.000E-01	2.000E 00	2.004105E 01	7.386226E 00	3.673354E 01	5.000508E 01	-1.239036E 02	-1.626988E 02
2.000E 00	2.000E 01	1.353237E 01	6.734056E 01	-1.154578E 02	8.265402E 01	-1.806598E 01	-1.843581E 00
2.000E 01	1.000E 02	1.311083E 01	3.306717E 01	-2.818373E 01	1.317985E 01	-3.386079E 00	3.783756E-01

AVERAGE Z**2

THIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
3.000E-02	2.000E-01	5.886949E 03	2.569043E 04	4.588111E 04	4.063175E 04	1.763981E 04	2.993267E 03
2.000E-01	2.000E 00	4.021611E 02	3.145767E 02	1.601862E 03	2.360938E 03	-4.223383E 03	-6.169355E 03
2.000E 00	2.000E 01	7.657007E-01	3.172782E-03	-5.051336E 03	2.984161E 03	-7.439178E 01	-3.118665E 02
2.000E 01	1.000E 02	9.036638E 02	-1.142769E 03	2.159005E 03	-1.577957E 03	5.243269E 02	-6.646352E 01

AFSEBIC

Z= 33

A= 75

COOLING RATE

THIN	TPAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
4.000E-02	2.000E-01	-7.716260E 00	5.321364E 01	1.140566E 02	1.204545E 02	6.241550E 01	1.292680E 01
2.000E-01	2.000E 00	-1.829698E 01	-5.153758E-01	4.158880E 00	-1.317577E 00	-2.008777E 01	-1.599099E 01
2.000E 00	2.000E 01	-2.038860E 01	2.033485E 01	-6.717009E 01	9.015033E 01	-5.434186E 01	1.226230E 01
2.000E 01	1.000E 02	-1.895937E 01	-2.130772E 00	4.826687E 00	-4.317720E 00	1.713556E 00	-2.496812E-01

AVERAGE Z

THIN	TPAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
4.000E-02	2.000E-01	2.510564E 01	2.125983E 01	4.808415E 00	-3.535244E-01	-1.599796E-02	6.320471E-02
2.000E-01	2.000E 00	2.260022E 01	1.595563E 00	-1.555644E-01	7.640396E 01	1.577113E 02	7.628091E 01
2.000E 00	2.000E 01	4.283284E 00	1.161831E 02	-2.000503E 02	1.689221E 02	-7.025098E 01	1.184811E 01
2.000E 01	1.000E 02	9.537977E 00	4.187209E 01	-3.062531E 01	1.046139E 01	-1.350151E 00	-1.502192E-02

AVERAGE Z**2

THIN	TPAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
4.000E-02	2.000E-01	5.443171E 02	4.966841E 02	-6.829014E 02	-1.377362E 03	-8.422815E 02	-1.812388E 02
2.000E-01	2.000E 00	5.106804E 02	6.643250E 01	-6.797209E 02	3.370650E 03	8.192910E 03	4.635684E 03
2.000E 00	2.000E 01	-4.130459E 02	5.641591E 03	-9.001906E 03	6.798184E 03	-2.399118E 03	3.249734E 02
2.000E 01	1.000E 02	6.493129E 03	-1.815076E 04	2.306876E 04	-1.429706E 04	4.364551E 03	-5.277466E 02

KRYPTON Z= 36 A= 84

COOLING RATE

THIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
5.000E-02	2.000E-01	5.675641E 01	4.008518E 02	8.516538E 02	8.893999E 02	4.587683E 02	9.121582E 01
2.000E-01	2.000E 00	-1.813640E 01	-1.518979E 00	2.831872E 00	6.121357E 00	-1.079979E 01	-1.574188E 01
2.000E 00	2.000E 01	-2.338300E 01	3.908789E 01	-1.058863E 02	1.264609E 02	-7.041264E 01	1.501634E 01
2.000E 01	1.000E 02	-2.639275E 01	1.954424E 01	-2.069597E 01	1.093239E 01	-2.881914E 00	3.063117E -01

AVERAGE Z

THIN	TMAX	E(0)	B(1)	B(2)	B(3)	B(4)	B(5)
5.000E-02	2.000E-01	2.737397E 02	1.421057E 03	3.108547E 03	3.389628E 03	1.820894E 03	3.839507E 02
2.000E-01	2.000E 00	2.477348E 01	1.092932E 01	-3.982480E 01	-5.751637E 00	1.585362E 02	1.513810E 02
2.000E 00	2.000E 01	4.204802E 01	-1.661638E 02	5.705164E 02	-7.922043E 02	4.957932E 02	-1.162575E 02
2.000E 01	1.000E 02	6.978986E 01	-1.225901E 02	1.552172E 02	-9.332669E 01	2.742764E 01	-3.189013E 00

AVERAGE Z**2

THIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
5.000E-02	2.000E-01	5.381816E 03	2.748930E 04	5.854017E 04	6.261657E 04	3.319315E 04	6.935469E 03
2.000E-01	2.000E 00	6.143159E 02	5.146052E 02	-1.716034E 03	-6.501152E 02	7.278070E 03	7.341254E 03
2.000E 00	2.000E 01	1.779943E 03	-1.090432E 04	3.636628E 04	-4.978460E 04	3.086954E 04	-7.187922E 03
2.000E 01	1.000E 02	6.402329E 02	8.449512E 02	-7.684343E 02	5.662356E 02	-2.226235E 02	3.274023E 01

RUBIDIUM $Z= 37$ $A= 86$

COOLING RATE

THIN	THAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
5.000E-02	2.000E-01	-5.461493E 01	-1.799198E 02	-3.396318E 02	-3.116768E 02	-1.413070E 02	-2.557811E 01
2.000E-01	2.000E 00	-1.605385E 01	-1.738418E 00	1.219649E 00	7.588205E 00	-8.653858E-01	-7.395018E 00
2.000E 00	2.000E 01	-2.280737E 01	3.345500E 01	-8.641444E 01	9.757053E 01	-5.117310E 01	1.026584E 01
2.000E 01	1.000E 02	-2.919264E 01	2.804677E 01	-3.113057E 01	1.739478E 01	-4.886711E 00	5.543989E-01

AVERAGE Z

THIN	THAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
5.000E-02	2.000E-01	-3.551545E 02	-1.946297E 03	-3.993596E 03	-3.978897E 03	-1.938713E 03	-3.712393E 02
2.000E-01	2.000E 00	2.509889E 01	1.476540E 01	-3.791385E 01	-2.680325E 01	1.285615E 02	1.439607E 02
2.000E 00	2.000E 01	6.204155E 01	-3.029177E 02	9.189507E 02	-1.207609E 03	7.330771E 02	-1.688443E 02
2.000E 01	1.000E 02	7.577080E 01	-1.359090E 02	1.686783E 02	-9.998761E 01	2.905424E 01	-3.344524E 00

AVERAGE Z**2

THIN	THAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
5.000E-02	2.000E-01	-6.908117E 03	-3.325844E 04	-6.914906E 04	-6.947125E 04	-3.402959E 04	-6.537672E 03
2.000E-01	2.000E 00	6.317834E 02	7.053801E 02	-1.597891E 03	-1.681687E 03	5.712418E 03	6.888762E 03
2.000E 00	2.000E 01	3.007220E 03	-1.941195E 04	5.820510E 04	-7.592031E 04	4.583462E 04	-1.051075E 04
2.000E 01	1.000E 02	-8.982063E 02	5.364047E 03	-5.801512E 03	3.312304E 03	-9.521514E 02	1.078834E 02

COOLING RATE

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
6.000E-02	2.000E-01	4.194087E 01	3.34093CE 02	7.382546E 02	8.071006E 02	4.347285E 02	9.184923E 01
2.000E-01	2.000E 00	-1.781824E 01	-1.649191E 00	-3.332628E 00	5.645095E 00	1.945447E 01	1.496553E 01
2.000E 00	2.000E 01	-1.704041E 01	-1.283663E 01	4.875841E 01	-8.235931E 01	6.045775E 01	-1.600262E 01
2.000E 01	1.000E 02	-2.070198E 01	2.374232E 00	-6.258366E-01	-4.403334E-01	2.768551E-01	-4.008014E-02

AVERAGE Z

TMIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
6.000E-02	2.000E-01	-5.385338E 00	-8.931606E 01	-1.598863E 02	-1.123506E 02	-1.607735E 01	8.870937E 00
2.000E-01	2.000E 00	2.499390E 01	2.470998E 01	-5.990358E 00	-6.282610E 01	-9.317650E 01	-4.771214E 01
2.000E 00	2.000E 01	7.657726E 01	-3.558628E 02	9.416096E 02	-1.097413E 03	5.967332E 02	-1.240668E 02
2.000E 01	1.000E 02	4.61511CE 02	-1.231903E 03	1.420449E 03	-8.139851E 02	2.325236E 02	-2.651840E 01

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
6.000E-02	2.000E-01	-7.756033E 02	-4.962152E 03	-1.017751E 04	-9.845680E 03	-4.425977E 03	-7.027112E 02
2.000E-01	2.000E 00	6.311016E 02	1.227413E 03	1.329366E 02	-3.542555E 03	-5.973207E 03	-3.122283E 03
2.000E 00	2.000E 01	3.898395E 03	-2.271358E 04	5.947928E 04	-6.840838E 04	3.666574E 04	-7.508598E 03
2.000E 01	1.000E 02	2.853944E 04	-7.772419E 04	8.821531E 04	-4.968874E 04	1.394148E 04	-1.561005E 03

THIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
6.000E-02	2.000E-01	4.177402E 01	3.529366E 02	8.282366E 02	9.635884E 02	5.536724E 02	1.251044E 02
2.000E-01	2.000E 00	-1.776430E 01	-1.387897E 00	-3.733358E 00	3.719864E 00	1.584268E 01	1.162981E 01
2.000E 00	2.000E 01	-1.530416E 01	-2.611612E 01	8.562155E 01	-1.290843E 02	8.812079E 01	-2.223192E 01
2.000E 01	1.000E 02	-2.971208E 00	-4.979866E 01	6.050545E 01	-3.610680E 01	1.064881E 01	-1.243395E 00

AVERAGE Z

THIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
6.000E-02	2.000E-01	-3.030696E 02	-1.785477E 03	-3.983287E 03	-4.382309E 03	-2.375700E 03	-5.063806E 02
2.000E-01	2.000E 00	1.475029E 01	2.626964E 01	5.974229E 00	-5.514798E 01	-1.487047E 02	-1.207260E 02
2.000E 00	2.000E 01	5.660063E 01	-1.844949E 02	4.282073E 02	-3.938374E 02	1.477869E 02	-1.569839E 01
2.000E 01	1.000E 02	5.314482E 02	-1.422496E 03	1.630344E 03	-9.293430E 02	2.641636E 02	-2.998024E 01

AVERAGE Z**2

THIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
6.000E-02	2.000E-01	-6.827270E 03	-3.973318E 04	-8.910375E 04	-9.854331E 04	-5.371954E 04	-1.152123E 04
2.000E-01	2.000E 00	6.194856E 02	1.314366E 03	7.862239E 02	-3.164929E 03	-8.738906E 03	-6.497949E 03
2.000E 00	2.000E 01	2.553027E 03	-1.118708E 04	2.477680E 04	-2.055435E 04	5.961605E 03	-6.264766E 01
2.000E 01	1.000E 02	3.994708E 04	-1.104021E 05	1.257555E 05	-7.118500E 04	2.007744E 04	-2.259231E 03

MOLYBDENUM Z= 42 A= 96

COOLING RATE

THIN	THAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
6.000E-02	2.000E-01	-1.391054E 02	-6.493335E 02	-1.365838E 03	-1.406464E 03	-7.086213E 02	-1.400571E 02
2.000E-01	2.000E 00	-1.772591E 01	-1.058217E 00	-3.583172E 00	1.660089E 00	8.565372E 00	4.532909E 00
2.000E 00	2.000E 01	-1.385096E 01	-3.678452E 01	1.140587E 02	-1.635634E 02	1.076260E 02	-2.642488E 01
2.000E 01	1.000E 02	3.992683E 01	-1.757093E 02	2.074927E 02	-1.214589E 02	3.531804E 01	-4.083832E 00

AVERAGE Z

THIN	THAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
6.000E-02	2.000E-01	4.992398E 01	8.506396E 01	-7.973177E 01	-3.870386E 02	-3.718835E 02	-1.120859E 02
2.000E-01	2.000E 00	2.449023E 01	2.684258E 01	1.299348E 01	-4.145381E 01	-1.496935E 02	-1.380536E 02
2.000E 00	2.000E 01	3.412437E 01	4.468081E 00	-1.301926E 02	3.624758E 02	-3.300305E 02	9.866466E 01
2.000E 01	1.000E 02	1.367133E 02	-2.287314E 02	2.005241E 02	-7.899527E 01	1.288693E 01	-4.473430E-01

AVERAGE Z**2

THIN	THAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
6.000E-02	2.000E-01	2.014558E 03	7.298914E 03	9.506961E 03	2.943082E 03	-2.491931E 03	-1.366985E 03
2.000E-01	2.000E 00	6.061704E 02	1.341397E 03	1.238729E 03	-2.327593E 03	-9.066148E 03	-7.680578E 03
2.000E 00	2.000E 01	1.039052E 03	1.543939E 03	-1.296176E 04	3.078173E 04	-2.555365E 04	7.730801E 03
2.000E 01	1.000E 02	-1.044010E 04	4.144755E 04	-5.565986E 04	3.642128E 04	-1.162727E 04	1.454795E 03

RHODIUM Z= 45 A=103

COOLING RATE

TMIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
7.000E-02	2.000E-01	1.376994E 02	8.404202E 02	1.786848E 03	1.874211E 03	9.737559E 02	2.008888E 02
2.000E-01	2.000E 00	-1.768007E 01	-9.738570E-02	-2.847141E 00	-3.325906E 00	1.002179E 00	1.379663E 00
2.000E 00	2.000E 01	-1.141403E 01	-5.045276E 01	1.395774E 02	-1.805608E 02	1.088862E 02	-2.480389E 01
2.000E 01	1.000E 02	-5.328139E 01	1.096783E 02	-1.387308E 02	8.676193E 01	-2.679433E 01	3.273048E 00

AVERAGE Z

TMIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
7.000E-02	2.000E-01	-3.006025E 02	-1.574088E 03	-3.044857E 03	-2.883747E 03	-1.353070E 03	-2.522223E 02
2.000E-01	2.000E 00	2.365568E 01	2.589635E 01	7.387447E 00	-2.148337E 01	6.529376E 01	9.799086E 01
2.000E 00	2.000E 01	-3.266263E 01	5.220852E 02	-1.547097E 03	2.152602E 02	-1.391557E 03	3.384241E 02
2.000E 01	1.000E 02	-1.058566E 03	3.298031E 03	-3.919706E 03	2.310768E 03	-6.757732E 02	7.848586E 01

AVERAGE Z**2

TMIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
7.000E-02	2.000E-01	-1.067288E 04	-5.545820E 04	-1.098845E 05	-1.069071E 05	-5.158441E 04	-9.912293E 03
2.000E-01	2.000E 00	5.732659E 02	1.239066E 03	1.092577E 03	-2.094847E 02	1.603416E 03	2.641056E 03
2.000E 00	2.000E 01	-3.788220E 03	1.907462E 04	-1.163665E 05	1.621908E 05	-1.048343E 05	2.546993E 04
2.000E 01	1.000E 02	-8.303419E 04	2.536534E 05	-3.013649E 05	1.774507E 05	-5.182918E 04	6.012012E 03

SILVER Z= 47 A=108

COOLING RATE

THIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
7.000E-02	2.000E-01	-3.795375E 01	-9.480473E 01	-1.814796E 02	-1.797662E 02	-9.073398E 01	-1.848865E 01
2.000E-01	2.000E 00	-1.770107E 01	2.015803E-01	-1.604788E 00	-2.902979E 00	-2.465746E 00	-4.111115E 00
2.000E 00	2.000E 01	-1.248988E 01	-3.786513E 01	9.418655E 01	-1.097435E 02	5.920938E 01	-1.193686E 01
2.000E 01	1.000E 02	-3.302240E 01	4.518471E 01	-5.654964E 01	3.457715E 01	-1.031558E 01	1.206081E 00

AVERAGE Z

THIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
7.000E-02	2.000E-01	-5.394950E 00	-1.813599E 02	-4.417952E 02	-4.672224E 02	-2.381528E 02	-4.769011E 01
2.000E-01	2.000E 00	2.331534E 01	2.459686E 01	2.154387E 01	-3.110730E 01	3.036504E 00	7.088077E 01
2.000E 00	2.000E 01	-5.718030E 01	6.730544E 02	-1.852864E 03	2.410827E 03	-1.471666E 03	3.806311E 02
2.000E 01	1.000E 02	2.136716E 02	-6.328191E 02	9.083823E 02	-6.318901E 02	2.143564E 02	-2.844839E 01

AVERAGE Z**2

THIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
7.000E-02	2.000E-01	-9.674550E 02	-9.204328E 03	-2.232062E 04	-2.433106E 04	-1.274322E 04	-2.617907E 03
2.000E-01	2.000E 00	5.486174E 02	1.158215E 03	1.540590E 03	-3.336128E 02	1.095252E 02	2.203301E 03
2.000E 00	2.000E 01	-5.600117E 03	5.043783E 04	-1.399720E 05	1.828771E 05	-1.117623E 05	2.585316E 04
2.000E 01	1.000E 02	4.967496E 03	-1.878245E 04	3.445510E 04	-2.775648E 04	1.038801E 04	-1.477527E 03

TEEN Z= 50 A=119

COOLING RATE

THIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
7.000E-02	2.000E-01	-2.720142E 01	-4.747627E 01	-9.237450E 01	-9.785225E 01	-4.605716E 01	-9.236912E 00
2.000E-01	2.000E 00	-1.772742E 01	4.136377E-01	-1.503533E 00	-4.428303E 00	8.540372E 00	1.216477E 01
2.000E 00	2.000E 01	-1.865140E 01	1.251001E 01	-5.279124E 01	8.774167E 01	-6.488446E 01	1.760886E 01
2.000E 01	1.000E 02	3.206134E 01	-1.511131E 02	1.794951E 02	-1.066184E 02	3.167570E 01	-3.758814E 00

AVERAGE Z

THIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
7.000E-02	2.000E-01	1.012843E 02	4.079011E 02	8.322642E 02	8.980066E 02	4.895918E 02	1.070228E 02
2.000E-01	2.000E 00	2.298685E 01	1.665106E 01	5.542841E 01	1.386567E 01	-2.177020E 02	-2.001744E 02
2.000E 00	2.000E 01	-2.920486E 01	3.910281E 02	-8.688850E 02	9.069314E 02	-4.271848E 02	7.105159E 01
2.000E 01	1.000E 02	6.134084E 02	-2.390597E 03	2.950388E 03	-1.801237E 03	5.445085E 02	-6.521707E 01

AVERAGE Z**2

THIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
7.000E-02	2.000E-01	3.083180E 03	1.305451E 04	2.550007E 04	2.646104E 04	1.404372E 04	3.004590E 03
2.000E-01	2.000E 00	5.303778E 02	8.076426E 02	2.860225E 03	1.498907E 03	-8.911180E 03	-9.036578E 03
2.000E 00	2.000E 01	-3.215697E 03	2.705484E 04	-5.943438E 04	6.031351E 04	-2.665655E 04	3.857208E 03
2.000E 01	1.000E 02	7.274269E 04	-2.19825E 05	2.709228E 05	-1.651687E 05	4.984656E 04	-5.958438E 03

XENON Z= 54 A=131

COOLING RATE

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
8.000E-02	2.000E-01	-2.027267E 01	-1.530175E 01	-3.074557E 01	-3.155124E 01	-1.600739E 01	-3.091098E 00
2.000E-01	2.000E 00	-1.778249E 01	2.776326E-01	1.901048E 00	-5.727093E 00	-6.456918E 00	2.998205E 00
2.000E 00	2.000E 01	-2.445709E 01	5.504901E 01	-1.625266E 02	2.174682E 02	-1.363026E 02	3.242958E 01
2.000E 01	1.000E 02	-3.693018E 01	6.802254E 01	-9.562685E 01	6.445815E 01	-2.107990E 01	2.700386E 00

AVERAGE Z

TMIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
8.000E-02	2.000E-01	-1.612164E 02	-1.091205E 03	-2.598436E 03	-3.017742E 03	-1.738551E 03	-3.985735E 02
2.000E-01	2.000E 00	2.556534E 01	1.945143E 00	7.525661E 00	1.189704E 02	7.082394E 01	-5.952649E 01
2.000E 00	2.000E 01	9.150919E 01	-5.787112E 02	1.935449E 03	-2.807403E 03	1.874038E 03	-4.698364E 02
2.000E 01	1.000E 02	-6.232300E 02	2.021506E 03	-2.433083E 03	1.466899E 03	-4.421467E 02	5.324440E 01

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
8.000E-02	2.000E-01	1.398493E 03	4.471387E 03	7.539434E 03	7.540645E 03	4.061307E 03	8.980940E 02
2.000E-01	2.000E 00	6.534578E 02	1.021993E 02	3.911807E 02	6.188945E 03	6.015180E 03	-6.423354E 02
2.000E 00	2.000E 01	8.855930E 03	-5.375176E 04	1.745354E 05	-2.502967E 05	1.662969E 05	-4.160487E 04
2.000E 01	1.000E 02	-7.966994E 04	2.474997E 05	-2.983927E 05	1.799612E 05	-5.420930E 04	6.519285E 03

CESIUM Z= 55 A=133

COOLING RATE

TMIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
9.000E-02	2.000E-01	-2.226471E 01	-2.891192E 01	-6.650677E 01	-7.731099E 01	-4.461736E 01	-1.006619E 01
2.000E-01	2.000E 00	-1.779565E 01	1.185689E-01	3.532875E 00	-4.526475E 00	-1.757306E 01	-1.006000E 01
2.000E 00	2.000E 01	-2.429091E 01	5.261754E 01	-1.516358E 02	1.979415E 02	-1.211167E 02	2.815828E 01
2.000E 01	1.000E 02	-9.336564E 00	-1.676851E 01	8.957417E 00	2.892433E-01	-1.461402E 00	3.103049E-01

AVERAGE Z

TMIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
9.000E-02	2.000E-01	8.626999E 01	3.629573E 02	7.997300E 02	9.342771E 02	5.489500E 02	1.285865E 02
2.000E-01	2.000E 00	2.659065E 01	1.164207E 00	-1.903210E 01	1.147274E 02	2.124507E 02	8.485561E 01
2.000E 00	2.000E 01	1.082264E 02	-7.033149E 02	2.258319E 03	-3.179688E 03	2.069898E 03	-5.078162E 02
2.000E 01	1.000E 02	-2.883174E 02	9.604810E 02	-1.096738E 03	6.317344E 02	-1.829121E 02	2.125168E 01

AVERAGE Z**2

TMIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
9.000E-02	2.000E-01	2.705206E 03	1.230703E 04	2.609896E 04	2.938972E 04	1.686177E 04	3.883692E 03
2.000E-01	2.000E 00	7.063511E 02	5.954717E 01	-9.638853E 02	5.898438E 03	1.311880E 04	6.682711E 03
2.000E 00	2.000E 01	8.331105E 03	-6.474255E 04	2.031044E 05	-2.834335E 05	1.838715E 05	-4.504638E 04
2.000E 01	1.000E 02	-3.617111E 04	1.142300E 05	-1.285915E 05	7.488050E 04	-2.188774E 04	2.564028E 03

BARIUM Z= 56 A=137

COOLING RATE

THIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
9.000E-02	2.000E-01	-2.004007E 01	-1.806400E 01	-4.671718E 01	-6.146550E 01	-3.997157E 01	-1.006615E 01
2.000E-01	2.000E 00	-1.779927E 01	-1.476108E-01	4.782498E 00	-2.258331E 00	-2.531186E 01	-2.108205E 01
2.000E 00	2.000E 01	-2.316821E 01	4.263641E 01	-1.190385E 02	1.495006E 02	-8.785661E 01	1.959862E 01
2.000E 01	1.000E 02	4.837304E 00	-6.015184E 01	6.171855E 01	-3.192465E 01	8.353925E 00	-8.826247E-01

AVERAGE Z

THIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
9.000E-02	2.000E-01	1.669243E 02	8.317686E 02	1.879463E 03	2.169884E 03	1.251546E 03	2.873108E 02
2.000E-01	2.000E 00	2.760315E 01	3.006613E 00	-4.135600E 01	8.707047E 01	2.955637E 02	1.948243E 02
2.000E 00	2.000E 01	1.150627E 02	-7.468716E 02	2.338029E 03	-3.215317E 03	2.047923E 03	-4.924790E 02
2.000E 01	1.000E 02	-2.877754E 02	9.316016E 02	-1.028834E 03	5.723740E 02	-1.598611E 02	1.789603E 01

AVERAGE Z**2

THIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
9.000E-02	2.000E-01	4.313772E 02	-9.247556E 02	-4.677227E 03	-6.240848E 03	-3.655699E 03	-8.184644E 02
2.000E-01	2.000E 00	7.604248E 02	1.580870E 02	-2.103106E 03	4.330852E 03	1.697478E 04	1.202521E 04
2.000E 00	2.000E 01	8.919535E 03	-6.842644E 04	2.097199E 05	-2.860721E 05	1.816263E 05	-4.361406E 04
2.000E 01	1.000E 02	-9.041398E 03	2.527563E 04	-2.054108E 04	7.621898E 03	-1.126427E 03	1.925208E 01

GADOLINIUM Z= 64 A=157

COOLING RATE

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
1.200E-01	2.000E-01	-3.460576E 01	-1.088745E 02	-2.694568E 02	-3.310134E 02	-2.029086E 02	-4.939537E 01
2.000E-01	2.000E 00	-1.738913E 01	-1.647227E 00	-2.882548E 00	6.146942E 00	2.401494E 01	1.974380E 01
2.000E 00	2.000E 01	-1.330247E 01	-3.790524E 01	1.191310E 02	-1.718326E 02	1.138282E 02	-2.819821E 01
2.000E 01	1.000E 02	-1.884755E 01	1.486681E 01	-2.992003E 01	2.291991E 01	-7.833732E 00	1.009846E 00

AVERAGE Z

TMIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
1.200E-01	2.000E-01	7.829712E 02	4.769144E 03	1.18E174E 04	1.483023E 04	9.240785E 03	2.298377E 03
2.000E-01	2.000E 00	2.856651E 01	3.67E16E 01	1.303005E 01	-1.091694E 02	-2.804431E 02	-1.961715E 02
2.000E 00	2.000E 01	9.672054E 00	2.763523E 02	-1.090200E 03	1.914294E 03	-1.456258E 03	3.995630E 02
2.000E 01	1.000E 02	-5.971814E 02	1.679043E 03	-1.732272E 03	9.004199E 02	-2.350369E 02	2.459679E 01

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
1.200E-01	2.000E-01	9.766746E 02	2.864692E 03	4.392320E 03	3.990840E 03	1.909497E 03	3.536531E 02
2.000E-01	2.000E 00	8.256833E 02	2.130140E 03	1.704353E 03	-6.944559E 03	-2.009690E 04	-1.444800E 04
2.000E 00	2.000E 01	-2.888314E 03	3.967111E 04	-1.416393E 05	2.308890E 05	-1.680504E 05	4.486652E 04
2.000E 01	1.000E 02	-7.517238E 04	2.052604E 05	-2.169131E 05	1.159632E 05	-3.125608E 04	3.390635E 03

TANTALUM Z= 73 A=181

COOLING RATE

THIN	THAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
1.000E-01	2.000E-01	-2.106464E 01	-2.204472E 01	-5.938495E 01	-8.063094E 01	-5.629388E 01	-1.640823E 01
2.000E-01	2.000E 00	-1.722614E 01	-5.284469E-02	-1.602685E 00	-3.671576E-02	-9.672115E-01	-2.133098E 00
2.000E 00	2.000E 01	-1.411167E 01	-2.009837E 01	3.880742E 01	-2.926431E 01	4.925379E 00	1.781689E 00
2.000E 01	1.000E 02	-2.552093E 02	6.934680E 02	-8.050032E 02	4.638064E 02	-1.328084E 02	1.513840E 01

AVERAGE Z

THIN	THAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
1.000E-01	2.000E-01	8.416551E 01	4.249365E 02	1.037798E 03	1.292121E 03	8.156040E 02	2.086197E 02
2.000E-01	2.000E 00	2.577701E 01	2.801825E 01	1.920009E 01	1.868616E 01	-1.210254E 01	-3.892940E 01
2.000E 00	2.000E 01	-9.882825E 01	9.544763E 02	-2.385586E 03	2.751611E 03	-1.444609E 03	2.780765E 02
2.000E 01	1.000E 02	5.298833E 03	-1.547667E 04	1.812443E 04	-1.052781E 04	3.038588E 03	-3.490029E 02

AVERAGE Z**2

THIN	THAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
1.000E-01	2.000E-01	4.649848E 03	2.714774E 04	6.616931E 04	8.100256E 04	4.970645E 04	1.223313E 04
2.000E-01	2.000E 00	6.700833E 02	1.461842E 03	1.788279E 03	1.805439E 03	5.645896E 02	-7.422163E 02
2.000E 00	2.000E 01	-9.618535E 03	7.640275E 04	-1.865344E 05	2.059947E 05	-1.000237E 05	1.683665E 04
2.000E 01	1.000E 02	6.857246E 05	-2.012877E 06	2.354584E 06	-1.366202E 06	3.939120E 05	-4.519909E 04

TUNGSTEN Z = 74 A = 184

COOLING RATE

THIN	THAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
1.000E-01	2.000E-01	5.340828E 00	1.560876E 02	4.171704E 02	5.502576E 02	3.567583E 02	9.042786E 01
2.000E-01	2.000E 00	-1.723894E 01	5.423752E-02	-1.221070E 00	4.411812E-01	-4.485821E 00	-7.836137E 00
2.000E 00	2.000E 01	-1.474880E 01	-1.439542E 01	2.105855E 01	-4.394746E 00	-1.106006E 01	5.616985E 00
2.000E 01	1.000E 02	-2.624260E 02	7.125586E 02	-8.250168E 02	4.742407E 02	-1.355175E 02	1.541889E 01

AVERAGE Z

THIN	THAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
1.000E-01	2.000E-01	1.555776E 02	9.075264E 02	2.344661E 03	3.050606E 03	1.995100E 03	5.250867E 02
2.000E-01	2.000E 00	2.560687E 01	2.746452E 01	1.880356E 01	2.109782E 01	-1.779688E 01	-5.671642E 01
2.000E 00	2.000E 01	-8.081505E 01	7.807107E 02	-1.793494E 03	1.856495E 03	-8.288591E 02	1.207945E 02
2.000E 01	1.000E 02	6.270438E 03	-1.827260E 04	2.132807E 04	-1.235512E 04	3.557784E 03	-4.078162E 02

AVERAGE Z**2

THIN	THAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
1.000E-01	2.000E-01	-1.057516E 04	-6.461370E 04	-1.535776E 05	-1.806057E 05	-1.050080E 05	-2.408997E 04
2.000E-01	2.000E 00	6.620789E 02	1.417530E 03	1.722973E 03	1.884802E 03	3.569429E 02	-1.384352E 03
2.000E 00	2.000E 01	-7.481742E 03	5.666677E 04	-1.210664E 05	1.084440E 05	-3.344618E 04	-8.941927E 01
2.000E 01	1.000E 02	8.064275E 05	-2.358791E 06	2.749159E 06	-1.590203E 06	4.572558E 05	-5.234089E 04

COOLING RATE

THIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
1.200E-01	2.000E-01	-8.806584E 02	-5.476148E 03	-1.384155E 04	-1.741388E 04	-1.090260E 04	-2.717910E 03
2.000E-01	2.000E 00	-1.727341E 01	4.217608E-01	-1.937531E 00	-9.930510E-01	4.078644E 00	2.802940E 00
2.000E 00	2.000E 01	-2.171187E 01	3.958749E 01	-1.288894E 02	1.878894E 02	-1.267756E 02	3.208405E 01
2.000E 01	1.000E 02	1.451132E 02	-5.106843E 02	6.336504E 02	-3.898860E 02	1.189153E 02	-1.438100E 01

AVERAGE Z

THIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
1.200E-01	2.000E-01	6.835973E 03	4.241523E 04	1.050920E 05	1.296459E 05	7.963356E 04	1.949093E 04
2.000E-01	2.000E 00	2.532104E 01	2.734290E 01	4.629555E 00	-6.335397E 00	1.072025E 02	1.210168E 02
2.000E 00	2.000E 01	8.090607E 01	-5.321836E 02	2.064758E 03	-3.355479E 03	2.460642E 03	-6.649321E 02
2.000E 01	1.000E 02	4.232590E 03	-1.189070E 04	1.343360E 04	-7.525184E 03	2.095061E 03	-2.322350E 02

AVERAGE Z**2

THIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
1.200E-01	2.000E-01	3.208620E 05	1.995556E 06	4.951495E 06	6.121311E 06	3.770381E 06	9.258468E 05
2.000E-01	2.000E 00	6.444465E 02	1.374137E 03	1.113673E 03	8.094683E 02	4.550645E 03	4.678008E 03
2.000E 00	2.000E 01	8.478105E 03	-7.260925E 04	2.588765E 05	-4.052998E 05	2.910839E 05	-7.761988E 04
2.000E 01	1.000E 02	5.630788E 05	-1.590281E 06	1.791573E 06	-1.000649E 06	2.777537E 05	-3.069549E 04

COOLING RATE

THIN	TPAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
1.200E-01	2.000E-01	-1.802466E 00	1.297200E 02	3.794717E 02	5.214385E 12	3.463330E 02	9.007402E 01
2.000E-01	2.000E 00	-1.732092E 01	5.957539E-01	-1.460514E 00	-1.690945E -00	3.218743E 00	2.399258E 00
2.000E 00	2.000E 01	-2.382712E 01	5.537012E 01	-1.701609E 02	2.367592E 12	-1.533781E 02	3.746571E 01
2.000E 01	1.000E 02	3.655247E 02	-1.168337E 03	1.413288E 03	-8.490737E 02	2.533425E 02	-3.003624E 01

AVERAGE Z

THIN	TPAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
1.200E-01	2.000E-01	-6.573511E 02	-4.250246E 03	-1.055364E 04	-1.299542E 04	-7.981004E 03	-1.957743E 03
2.000E-01	2.000E 00	2.497398E 01	2.742563E 01	1.242171E 01	-3.124921E 01	6.481328E 01	1.273108E 02
2.000E 00	2.000E 01	1.730723E 02	-1.259165E 03	4.122215E 03	-6.014883E 03	4.060326E 03	-1.028155E 03
2.000E 01	1.000E 02	-2.899711E 03	9.539387E 03	-1.213698E 04	7.630082E 03	-2.368479E 03	2.906008E 02

AVERAGE Z**2

THIN	TPAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
1.200E-01	2.000E-01	-2.450561E 04	-1.524637E 05	-3.691300E 05	-4.424136E 05	-2.639048E 05	-6.279341E 04
2.000E-01	2.000E 00	6.285464E 02	1.362917E 03	1.344066E 03	-2.257288E 03	2.780839E 03	4.735449E 03
2.000E 00	2.000E 01	1.747198E 04	-1.433044E 05	4.585096E 05	-6.625753E 05	4.451185E 05	-1.123477E 05
2.000E 01	1.000E 02	-4.291640E 05	1.393655E 06	-1.764749E 06	1.106627E 06	-3.426838E 05	4.194978E 04

COOLING RATE

THIN	TMAX	A(0)	A(1)	A(2)	A(3)	A(4)	A(5)
1.200E-01	2.000E-01	-8.285376E 01	-3.837544E 02	-9.089529E 02	-1.083649E 03	-6.478406E 02	-1.550439E 02
2.000E-01	2.000E 00	-1.734898E 01	6.419893E-01	-9.527458E-01	-1.733278E 00	6.306658E-01	-6.524034E-01
2.000E 00	2.000E 01	-2.391284E 01	5.524454E 01	-1.667912E 02	2.280661E 02	-1.453095E 02	3.493993E 01
2.000E 01	1.000E 02	4.563799E 02	-1.443843E 03	1.738152E 03	-1.039432E 03	3.087976E 02	-3.646432E 01

AVERAGE Z

THIN	TMAX	B(0)	B(1)	B(2)	B(3)	B(4)	B(5)
1.200E-01	2.000E-01	5.742969E 02	3.371921E 03	8.292867E 03	1.028191E 04	6.378805E 03	1.581481E 03
2.000E-01	2.000E 00	2.477446E 01	2.675441E 01	2.240800E 01	-3.736302E 01	2.825087E 00	8.351793E 01
2.000E 00	2.000E 01	1.568710E 02	-1.438030E 03	4.590348E 03	-6.556207E 03	4.341012E 03	-1.080398E 03
2.000E 01	1.000E 02	-6.555238E 03	2.048513E 04	-2.515361E 04	1.531943E 04	-4.625863E 03	5.541890E 02

AVERAGE Z**2

THIN	TMAX	C(0)	C(1)	C(2)	C(3)	C(4)	C(5)
1.200E-01	2.000E-01	2.297430E 04	1.367155E 05	3.341231E 05	4.113737E 05	2.535701E 05	6.246450E 04
2.000E-01	2.000E 00	6.193340E 02	1.333349E 03	1.728784E 03	-5.350281E 02	5.756398E 01	2.710245E 03
2.000E 00	2.000E 01	1.966860E 04	-1.595747E 05	5.002003E 05	-7.090886E 05	4.677879E 05	-1.161040E 05
2.000E 01	1.000E 02	-9.579429E 05	2.977747E 06	-3.656658E 06	2.226982E 06	-6.723971E 05	8.054350E 04

COOLING RATE

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
1.200E-01	2.000E-01	1.691653E 01	2.201134E 02	5.586077E 02	7.009241E 02	4.361924E 02	1.079456E 02
2.000E-01	2.000E 00	-1.741199E 01	6.86449E-01	-5.834381E-01	-2.841552E 00	3.836976E 00	5.888367E 00
2.000E 00	2.000E 01	-2.290993E 01	4.392270E 01	-1.229625E 02	1.551537E 02	-9.114046E 01	2.017552E 01
2.000E 01	1.000E 02	1.559316E 02	-4.964221E 02	5.616072E 02	-3.150930E 02	8.764073E 01	-9.663622E 00

AVERAGE Z

TMIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
1.200E-01	2.000E-01	-3.153101E 03	-1.98241E 04	-4.934175E 04	-6.116369E 04	-3.780362E 04	-9.322402E 03
2.000E-01	2.000E 00	2.447235E 01	2.006822E 01	5.965723E 01	3.778276E-01	-2.404648E 02	-2.014667E 02
2.000E 00	2.000E 01	-2.025621E 02	-1.413102E 03	4.244367E 03	-5.684184E 03	3.531764E 03	-8.261226E 02
2.000E 01	1.000E 02	-1.387057E 04	4.207474E 04	-5.047426E 04	3.007213E 04	-8.899043E 03	1.046697E 03

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
1.200E-01	2.000E-01	1.577811E 04	9.17406E 04	2.210348E 05	2.693028E 05	1.646058E 05	4.027007E 04
2.000E-01	2.000E 00	5.030513E 02	1.032229E 03	3.297447E 03	1.061819E 03	-1.054742E 04	-9.816633E 03
2.000E 00	2.000E 01	1.950489E 04	-1.505810E 05	4.452275E 05	-5.913722E 05	3.652132E 05	-8.483175E 04
2.000E 01	1.000E 02	-2.075153E 06	6.281865E 06	-7.538192E 06	4.492698E 06	-1.329854E 06	1.564514E 05

RADON Z= 86 A=222

COOLING RATE

TMIN	TMAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
1.200E-01	2.000E-01	1.653728E 00	1.191212E 02	2.984966E 02	3.719575E 02	2.306947E 02	5.708704E 01
2.000E-01	2.000E 00	-1.745135E 01	6.032115E-01	-3.133017E-01	-3.943299E 00	7.126507E 00	1.363919E 01
2.000E 00	2.000E 01	-1.905616E 01	1.102964E 01	-2.072095E 01	9.817985E 00	4.891017E 00	-3.730777E 00
2.000E 01	1.000E 02	1.487831E 00	-6.324101E 00	-5.280840E 01	6.573154E 01	-2.916037E 01	4.529058E 00

AVERAGE Z

TMIN	TMAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
1.200E-01	2.000E-01	-1.822324E 03	-1.152310E 04	-2.870455E 04	-3.558558E 04	-2.199536E 04	-5.424266E 03
2.000E-01	2.000E 00	2.576372E 01	7.401569E 00	5.306744E 01	1.024646E 02	-1.972741E 02	-3.034636E 02
2.000E 00	2.000E 01	1.156715E 02	-6.604216E 02	1.823377E 03	-2.087757E 03	1.050869E 03	-1.837929E 02
2.000E 01	1.000E 02	-9.246793E 03	2.710209E 04	-3.132355E 04	1.798149E 04	-5.125996E 03	5.806794E 02

AVERAGE Z**2

TMIN	TMAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
1.200E-01	2.000E-01	-1.357754E 04	-8.976969E 04	-2.279748E 05	-2.855828E 05	-1.778233E 05	-4.413238E 04
2.000E-01	2.000E 00	6.652744E 02	4.113281E 02	2.831410E 03	5.871699E 03	-7.315422E 03	-1.331754E 04
2.000E 00	2.000E 01	9.371992E 03	-6.318485E 04	1.650151E 05	-1.763630E 05	7.936494E 04	-1.085551E 04
2.000E 01	1.000E 02	-1.359307E 06	3.967673E 06	-4.583546E 06	2.629194E 06	-7.487024E 05	8.469938E 04

COOLING RATE

THIB	THAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
1.300E-01	2.000E-01	-2.036539E 01	-2.026511E 01	-5.287439E 01	-6.923624E 01	-4.541544E 01	-1.171118E 01
2.000E-01	2.000E 00	-1.750751E 01	2.643170E-01	2.718144E 00	-2.249189E 01	-1.359796E 01	-9.364738E 00
2.000E 00	2.000E 01	-1.391504E 01	-3.090959E 01	1.024687E 02	-1.558457E 02	1.087274E 02	-2.831969E 01
2.000E 01	1.000E 02	-2.480498E 02	7.439761E 02	-9.453206E 02	5.912407E 02	-1.824275E 02	2.225510E 01

AVERAGE Z

THIB	THAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
1.300E-01	2.000E-01	3.137454E 02	1.846652E 03	4.673629E 03	5.977230E 03	3.818579E 03	9.729409E 02
2.000E-01	2.000E 00	2.971381E 01	1.793510E 00	-3.713678E 01	1.162935E 02	2.858772E 02	1.465962E 02
2.000E 00	2.000E 01	-4.425139E 01	6.506880E 02	-2.135265E 03	3.434746E 03	-2.540479E 03	6.966370E 02
2.000E 01	1.000E 02	-1.045039E 03	1.354970E 03	6.375422E 02	-1.642719E 01	8.393306E 02	-1.380820E 02

AVERAGE Z**2

THIB	THAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
1.300E-01	2.000E-01	9.003879E 02	6.845190E 02	-3.079759E 03	-6.860109E 03	-5.555820E 03	-1.652404E 03
2.000E-01	2.000E 00	8.811497E 02	1.079726E 02	-2.056073E 03	6.263488E 03	1.842761E 04	1.108070E 04
2.000E 00	2.000E 01	-9.340887E 03	9.032313E 04	-2.979839E 05	4.690480E 05	-3.401655E 05	9.196119E 04
2.000E 01	1.000E 02	-3.020199E 04	-1.969330E 05	5.780128E 05	-5.361556E 05	2.125957E 05	-3.104413E 04

THIN	THAX	A (0)	A (1)	A (2)	A (3)	A (4)	A (5)
1.300E-01	2.000E-01	-1.495556E 01	1.580063E 01	4.267615E 01	5.603012E 01	3.551035E 01	8.939165E 00
2.000E-01	2.000E 00	-1.751079E 01	-3.202753E-02	3.790327E 00	1.176829E-01	-2.136255E 01	-2.083760E 01
2.000E 00	2.000E 01	-1.284022E 01	-3.894788E 01	1.228803E 02	-1.779799E 02	1.189095E 02	-2.980162E 01
2.000E 01	1.000E 02	-5.994968E 01	1.521015E 02	-2.043828E 02	1.302916E 02	-3.997438E 01	4.763369E 00

AVERAGE Z

THIN	THAX	B (0)	B (1)	B (2)	B (3)	B (4)	B (5)
1.300E-01	2.000E-01	-2.728853E 02	-1.995620E 03	-5.368516E 03	-7.103316E 03	-4.671402E 03	-1.223613E 03
2.000E-01	2.000E 00	3.161530E 01	8.357098E 00	-7.346013E 01	4.251910E 01	3.891675E 02	3.251565E 02
2.000E 00	2.000E 01	-9.547400E 01	1.048103E 03	-3.252743E 03	4.861246E 03	-3.374666E 03	8.772439E 02
2.000E 01	1.000E 02	4.324414E 03	-1.504300E 04	2.046761E 04	-1.351976E 04	4.365316E 03	-5.534480E 02

AVERAGE Z**2

THIN	THAX	C (0)	C (1)	C (2)	C (3)	C (4)	C (5)
1.300E-01	2.000E-01	9.630516E 03	5.629910E 04	1.381985E 05	1.723639E 05	1.080501E 05	2.713863E 04
2.000E-01	2.000E 00	9.955994E 02	4.987815E 02	-4.077736E 03	1.727808E 03	2.319399E 04	2.037862E 04
2.000E 00	2.000E 01	-1.532802E 04	1.367465E 05	-4.280375E 05	6.341909E 05	-4.360135E 05	1.124886E 05
2.000E 01	1.000E 02	9.173417E 05	-3.088004E 06	4.073355E 06	-2.630039E 06	8.345447E 05	-1.043701E 05

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APPENDIX A: Average Ion Model

A partially ionized element in a plasma will have a distribution of charge states. For low-density, transparent plasmas the steady-state (coronal equilibrium) distribution of ionic species is determined by the electron temperature. For example, in coronal equilibrium iron ions in a 1.5-keV, 10^{14} electrons/cm³, hydrogen plasma occur primarily as Fe XXI, Fe XXII, Fe XXIII, Fe XXIV, and Fe XXV. The most straightforward method of computing the radiation and the average charge state of the impurities is to first calculate the distribution of ionic species. This can be done by solving a system of equations

$$\frac{\partial n_i}{\partial t} = -(I_{i \rightarrow i+1} + R_{i \rightarrow i-1})n_i + R_{i+1 \rightarrow i} n_{i+1} + I_{i-1 \rightarrow i} n_{i-1} \quad (A1)$$

where n_i is the density of ions with the charge state $q = i$, $I_{i \rightarrow i+1}$ is the ionization rate from q to $q+1$ and $R_{i \rightarrow i-1}$ is the recombination rate from q to $q-1$. Steady-state distributions are determined by setting the left hand side of (A1) equal to zero. Finally, the total radiated power can be found by summing the contributions of line radiation, recombination radiation and bremsstrahlung for each ionic species.

Reasonable values for the ionization, recombination, excitation and radiative decay rates for low-Z elements ($Z \lesssim 26$)

are available in the astrophysical literature and the number of equations (A1) is small ($\sim Z$). As a consequence, this prescription has been successfully exploited for the calculation of low-Z impurity radiation^{1,2,3}.

Unfortunately, the rates for moderate-and high-Z elements are not well known. Typically they are only accurate to factors of 2 to 4; and the number of equations (A1) is large. To circumvent these difficulties a simpler model was used in our calculation. A useful approximation, which has been successfully employed in the calculation of high-Z opacities, is to replace the different ionic species for each impurity element by a single, fictitious "average ion". The average ion is a statistical average of all possible charge states of the element.

As an illustration of this approach, consider a 10^{14} electrons/cm³, hydrogen plasma with 10^{12} iron ions/cm³ at 1.5 keV. The electron populations in coronal equilibrium for the principal shells $n = 1, 2, 3$, and 4 of the average iron ion are:

$$P_1 = 2.000 \quad P_2 = 1.099 \quad P_3 = 2.897 \times 10^{-10} \quad P_4 = 1.486 \times 10^{-10}.$$

The corresponding ionic species densities n_i are listed in Table A1. In this example, the K and L shell electron populations of the average ion are just equal to the weighted sum of the contributions of each of the ionization states. The populations of the higher shells represent excited electrons.

The "average ion" approximation was originally developed for the treatment of plasmas in local-thermodynamic-equilibrium.^{4,5} It has also been applied in nonequilibrium emission and absorption calculations in high-density, opaque plasmas.⁶ We have further modified this model for nonequilibrium calculations in low-density, transparent plasmas.

In thermodynamic equilibrium, the ionic species fractions f_i are determined by the Saha equilibrium equation.⁵ The principal electron shell populations P_n (n is the principal quantum number) for an average ion are given by the weighted average of the principal shell electron populations of each ionic species $P_n(i)$:

$$P_n = \sum_i f_i P_n(i) \quad (A2)$$

where the sum is over the ionic species. In our calculation, the plasma is not in thermal equilibrium and time-dependent principal shell populations P_n of the average ion are determined by the solution of a set of nonlinear related-rate equations for these populations:

$$\frac{d}{dt} P_n = S_n - L_n \quad (A3)$$

where S_n is the rate at which electrons are added to n th shell by (1) dielectronic, radiative, and three body recombination, (2) collisional excitation from a lower shell, and (3) radiative

decay from a higher shell; and L_n is the rate at which electrons are removed from the n th shell by (1) collisional excitation to higher shells, (2) radiative decay to lower shells, and (3) ionization. These can be written as:

$$n_z S_n = Q_n \cdot (R_n + \sum_{m>n} DL_{nm} \cdot P_m + \sum_{\ell<n} C_{n\ell} \cdot P_\ell) + D_n \quad (A4)$$

$$n_z L_n = P_n \cdot (C_n + \sum_{m>n} C_{nm} \cdot Q_m + \sum_{\ell<n} DL_{n\ell} \cdot Q_\ell)$$

where n_z is the impurity ion density,

$Q_n = (2n^2 - P_n) / 2n^2$ is the fraction of electron vacancies in the n^{th} shell,

R_n = Radiative recombination rate,

DL_{nm} = Downward line transition rate $m \rightarrow n$,

C_{nm} = Upward line transition rate $m \rightarrow n$,

C_n = Collisional ionization rate, and

D_n = Excitation rate to the n^{th} shell due to Dielectronic Recombination.

$R_n = \alpha_n + \alpha_{3-b}^n$ is the sum of the radiative and 3-body recombination rates to the n^{th} shell given by equations (B5) and (B16) respectively in Appendix B. $DL_{nm} = A_{nm} + C_{nm}^d$ where A_{nm} is the Einstein coefficient for the spontaneous, radiative line transition $m \rightarrow n$ and C_{nm}^d is the collisional de-excitation rate coefficient obtained from the collisional excitation rate C_{mn} by the principle of detailed balance. The explicit form of the collisional excitation rate $C_{\ell n}$ is given in equation (B18). The collisional ionization C_n of electrons in shell n is given

by equation (B2). The plasma is assumed to be transparent so there are no excitations or ionizations due to the absorption of radiation. Finally, D_n is the rate at which electrons are added to the n^{th} shell through dielectronic recombination. Dielectronic recombination occurs when a free electron is captured in a high-lying autoionizing level by exciting a bound electron to shell n . We assume in our model that the captured electron cascades immediately to the ground state replacing the excited electron. In this case

$$D_n = \sum_i f_i \alpha_{\text{dr}}(i)$$

The sum is taken over ionic species with excited electrons in the n^{th} shell and f_i is the fractional density of the i^{th} charge state. $\alpha_{\text{dr}}(i)$ is the total dielectronic recombination rate with excited electrons in the n^{th} shell which is given by equation (B7) with the sum over j restricted to sublevels of shell n .

In our calculation, these coupled nonlinear equations are solved numerically using a Newton-Rapheson method. At each time step, the resulting electron populations are used to calculate the average ion energy levels using a Bohr model with screening factors and relativistic corrections [Eq. (B1)]. Finally, with these average ion energy levels, populations and corresponding transition rates, the emission due to bremsstrahlung, radiative and dielectronic recombination, and line transitions is determined. (Explicit equations for these emission rates are given in Appendix B.)

The coronal equilibrium values for the radiation and mean charge state are obtained by iterating this calculation until steady-state is achieved.

The rates for radiative recombination, collisional excitation, and collisional ionization for various ionic species differ primarily in the values for the principal shell populations and energy levels. Since the energy levels of adjacent ionization states are not significantly different and the total rates are approximately linear in the numbers of principal shell electrons, the average ion model is adequate for the calculation of these contributions to the impurity radiation.

In addition, the impurity bremsstrahlung is also accurately calculated in the average ion approximation since it depends upon $\bar{Z}^2 \sim \bar{Z}^2 = Z_{\text{Av. Ion}}^2$.

However, dielectronic recombination and $\Delta n = 0$ transition rates are more sensitive to specific ionization states. Although exact knowledge of the ionization states was sacrificed in adopting the average ion model, approximate ionic species densities are recovered for the calculation of these processes by specifying ratios between adjacent ionic species and by requiring that:

$$P_n = \sum_i f_i P_n(i), \quad \sum_i f_i = 1 \quad (\text{A3})$$

where f_i is the fractional density of the i^{th} ionization state and $P_n(i)$ is the n shell population of the i^{th} state. In steady-

state, the density ratios are determined by coronal equilibrium:

$$f_i/f_{i+1} = R_{i+1}/C_i \quad (A4)$$

where R_{i+1} is the recombination rate of the $i+1$ species and C_i is the collisional ionization rate of the i^{th} species. For time dependent problems, the right-hand side of Eq. (A3) is multiplied by an additional unknown variable $x(t)$ which is determined from Eqs. (A2) and (A3) which along with (A4) give $N + 1$ equations for N unknown species densities. Since Eq. (A3) emphasizes steady-state ratios, this prescription is most accurate for systems close to steady state.

This procedure for the determination of the ionic species densities, which are necessary for the calculation of the radiation due to dielectronic recombination and $\Delta n = 0$ transitions, is equivalent to a full ionic species calculation. However, it is expected to be less accurate for time-dependent calculations than a nonequilibrium "collisional-radiative" model.⁷ Table A1 shows a comparison of the steady state (coronal equilibrium) ionic species fractions for the principal iron ions in a 1.5-keV hydrogen plasma with an electron density of 10^{14} electrons/cm³ with those given by a full ionic species calculation.¹ In addition, comparisons of the radiation rates in coronal equilibrium with those obtained by full ionic species calculations are shown in the figures for 14 elements.

T A B L E A1

Ion Species

Fe	XXI	XXII	XXIII	XXIV	XXV
Average Ion Model	0.0404	0.0850	0.1505	0.2540	0.4467
Merts, et.al.[1]	0.020	0.056	0.131	0.261	0.525

APPENDIX B: Atomic Physics Formulae

1. General Comments

In solving the rate equations [Eq. (A3)], a number of formulae for various atomic processes are needed. In particular, expressions are required for the rates of collisional ionization and excitation, radiative, dielectronic, and 3-body recombination. To calculate the total radiative cooling one needs additional formulae for recombination, and expressions which allow one to compute the radiative losses due to bremsstrahlung and discrete line emission.

Our choices for the various rates are dictated by both the structure of the code and the physical parameters of the problems of interest. The "average ion" character of the atomic model means that general expressions of reasonable accuracy are much more useful than a (necessarily incomplete) collection of individual ionic rates—clearly, the code is not designed for use in detailed spectral diagnostics. The densities of interest, $N_e \sim 10^{10} - 10^{16} \text{ cm}^{-3}$, imply that metastable levels will be collisionally de-excited while allowed transitions will proceed almost entirely by radiative decay. The temperatures of importance, $T > 100 \text{ eV}$, mean that all elements will exhibit a substantial degree of ionization (i.e., we do not need formulae which are accurate for neutral and near-neutral species). In addition, our plasmas will typically have $I_z/T \sim \text{few}$ where I_z is the ionization potential of an ion with charge z , so that our results need to be most appropriate for those regimes. Finally, our relationships should be relatively simple so that

the code can be used efficiently for time dependent as well as steady-state problems. This will also facilitate changes in the code as more accurate data become available.

Using these general criteria, we have adopted the set of atomic parameters and rate coefficients described below. Unless otherwise specified, we will use z as the average ionic charge, n the principal quantum number, and $I_{z,n}$ as the ionization potential (in keV) of an electron in the n th shell. Temperatures, T , will be expressed in keV and electron and ion densities, n_e and n_z , respectively, will be given in cm^{-3} .

2. Energy Levels

The isolated atom's energy level is taken to be the arithmetic mean of the lowest and highest sublevels for hydrogenic ions with effective nuclear charge Z_n as seen by the electron in shell n . Z_n is determined by the method of screening constants, using Harris Mayer's⁸ screening constants and the electron populations of all the shells. The hydrogenic formula used for the sublevel energies, $E_{n,k}$, is the Pauli approximation to the Dirac formula:

$$E_{n,k} = 0.0136 \left(\frac{Z_n}{n} \right)^2 \left[1 + \frac{(\alpha Z_n)^2}{n} \left(\frac{1}{k} - \frac{3}{4n} \right) \right] \quad (\text{B1})$$

where $k = 1, \dots, n$ and $E_{n,k}$ is in keV and α is the fine structure constant.

3. Collisional Ionization

The rate of collisional ionization for an electron in shell n can be written as

$$C_{z,n} = 1.86 \times 10^7 n_z n_e T^{1/2} e^{-x_n} (1 - e^{-x_n}) \left(\frac{I_H}{I_{z,n}} \right)^2 \Gamma_{z,n} \text{ cm}^{-3} \text{ s}^{-1}, \quad (\text{B2})$$

where $x_n = I_{z,n}/T$ and I_H is the ionization potential of hydrogen = 0.0136 keV. The various formulae in the literature differ primarily in their choice of the Gaunt factor $\Gamma_{z,n}$. For example, Jordan⁹ chooses $\Gamma = 1.98$ for ground state ions, Jacobs¹⁰ uses $\Gamma = 2.42 - 1.72/z + 0.19/z^2$, and Sampson and Golden¹¹ derive a very complicated formula involving fractional exponential integrals. Lotz¹² provides the best compilation of empirical results on which many of the general expressions are based. We have combined these various prescriptions to yield the formula

$$\Gamma_{z,n} = 12.18 \exp(-n/n+5) (1 + 0.0335 n) (1 - 0.622/z - 0.0745/z^2) |f(y)| \quad (\text{B3})$$

where

$$f(y) = 0.23 + 0.046 y + 0.1074 y^2 - 0.0459 y^3 - 0.01505 y^4 \quad (\text{B4})$$

and $y = \log x_n/4$.

4. Radiative Recombination

The rate of radiative recombination to level n of a hydro-

genic ion can be written as¹³

$$\alpha_n = 5.20 \times 10^{-14} n_e n_z x_n^{3/2} \exp(x_n) E_1(x_n) \text{ cm}^{-3} \text{ s}^{-1} \quad (\text{B5})$$

where E_1 is the first exponential integral.

The continuum energy radiated in this process is

$$\lambda_{rr}^n = 8.32 \times 10^{-23} n_e n_z x_n^{1/2} I_{z,n} Q_n \text{ erg cm}^{-3} \text{ s}^{-1}, \quad (\text{B6})$$

In both (B5) and (B6) we have assumed unit Gaunt factors in the photo-ionization cross sections. Tarter^{14,15} and Aldrovandi and Peguignot^{16,17} have computed values of α for complex ions, but the differences between their results and Eq.(B4) are small compared with other uncertainties in the calculation.

5. Dielectronic Recombination

We follow the basic scheme of Burgess¹⁸ and write the rate of dielectronic recombination (summed over all levels) in the form

$$\alpha_{dr} = 7.59 \times 10^{-14} n_e n_z \frac{B(z)D(z,T)}{T^{3/2}} \sum_j f_{ji} A(y) \exp(-\bar{E}/kT) \quad (\text{B7})$$

where i is the initial state of the recombining ion, z its charge, v_i and v_j are the effective principal quantum numbers of states i and j , $E_{ij} = v_i^{-2} - v_j^{-2}$, $y = (z+1) E_{ij}$, f_{ji} are the oscillator strengths for the exciting transition (see section 8), and

$$B(z) = z^{1/2} (z + 1)^{5/2} (z^2 + 13.4)^{-1/2} \quad (B8)$$

$$\bar{E}/kT = (z + 1)^2 E_{ij} / (73.5 \text{ aT}) \quad (B9)$$

$$a = 1 + 0.015 z^3 / (z + 1)^2 \quad (B10)$$

The quantities $A(y)$ and $D(z, T)$ are different, depending on whether the excitation involves a change in principal quantum number. For $\Delta n = 0$ transitions we adopt

$$A(y) = y^{1/2} / (1 + 0.105 y + 0.015 y^2) \quad (B11)$$

$$D(z, T) = \frac{n_t/200}{1 + n_t/200} ; n_t^7 = 4.77 \times 10^{18} z^6 T^{1/2} / n_e \quad (B12)$$

while for $\Delta n \neq 0$ excitations we use,

$$A(y) = \frac{y^{1/2}}{2} / (1 + 0.210 y + 0.030 y^2) \quad (B13)$$

and

$$D(z, T) = \frac{0.0015 [(z + 1) n_t]^2}{1 + 0.0015 [(z + 1) n_t]^2} \quad (B14)$$

Equation (B11) is Burgess' original prescription, while (B13) is a modification suggested by Merts et al.¹ $D(z,T)$, which describes the decrease in α_{dr} due to collisional interruption at high densities, is taken from Burgess,¹⁹ prescription for CaII for $\Delta n = 0$ transitions, and from Shore's calculations for helium-like ions²⁰ for $\Delta n \neq 0$ transitions. Since Burgess' calculations are in principal limited to moderate z ions ($z \lesssim 20$ or so), and the density formulae are clearly quite limited in their scope, substantial work still remains with regard to accurate dielectronic formulae. In lieu of such results, however, we have simply assumed that the above expressions are valid for all z and all densities.

To good approximation the total energy radiated away in dielectronic recombination is given by

$$\lambda_{dr} = (I_z + \langle E_j \rangle) \alpha_{dr} \quad (B15)$$

where $\langle E_j \rangle$ is the average excitation energy (for practical purposes this is usually equal to the energy of the lowest excited state).

6. 3-Body Recombination

Although 3-body recombination will usually not be of interest at tokamak densities, its inclusion in the code is useful because it insures that thermodynamic equilibrium will be attained as the density increases. From detailed balancing considerations one obtains

$$\alpha_{3-b}^n = \frac{5.25 \times 10^{-27}}{T^{3/2}} n_e \frac{g_z}{g_{z-1,n}} \exp(I_n/kT) C_{z-1,n} \text{ cm}^{-3} \text{ s}^{-1} \quad (\text{B16})$$

where the g's are statistical weights.

7. Bremsstrahlung

The radiative losses due to nonrelativistic electron-ion bremsstrahlung can be written as

$$\lambda_{br} = 4.85 \times 10^{-24} n_e n_z z^2 T^{1/2} g_{ff}(z,T) \text{ ergs cm}^{-3} \text{ s}^{-1} \quad (\text{B17})$$

where the free-free Gaunt factor g_{ff} is given by Karzas and Latter²¹. At very high temperatures ($T > 50$ keV) corrections due to both relativistic effects and electron-electron terms should be included, but this will be of little importance for currently envisaged tokamak plasmas.

8. Collisional Excitation

The dominant energy loss mechanism in most tokamak regimes will be radiative decay following collisional excitation.* The collisional excitation rate can be written in the form²²

$$C_{nj} = 4.99 \times 10^{-10} n_e n_z \frac{f_{nj}}{E_{nj}} \exp(-E_{nj}/kT) g_{nj} \text{ cm}^{-3} \text{ s}^{-1} \quad (\text{B18})$$

* In calculating the total radiative losses, it is immaterial whether this decay proceeds by 1- or 2-photon emission. To determine the actual spectrum of emitted radiation, one has explicitly to include 2-photon processes, particularly because of the strong z dependence of their transition probability

$\propto z^{8-10}$.

where f_{nj} is the oscillator strength for $j \rightarrow n$, E_{nj} the excitation energy, and g_{nj} the Gaunt factor. There have been many calculations of E , f , and g values in the literature, but principally for ions of low to moderate z elements. Our procedure has been to use the available tabulations for relatively light elements^{23,24,25} and references contained therein, and some recent relativistic Hartree-Fock calculations by Scofield²⁶ to obtain approximate formulae for E and f for the ions of interest. Our Gaunt factors are based on the work by Bely²⁷, Blaha²⁸, and Golden and Sampson²⁹.

For transitions in which the principal quantum number changes, we use the energies computed by the code (see section B2) and hydrogenic oscillator strengths modified by the following factor:

$$\left. \begin{aligned} f_{n,n'} &= f_{n,n'}^{\text{Hy}}, \text{ if } n' > n+1 \\ f_{n,n+1} &= f_{n,n+1}^{\text{Hy}} \left(\frac{E_{n,n+1}^{\text{Hy}}}{E_{n,n+1}^{\text{code}}} \right) Y(n, P_n), \text{ otherwise} \end{aligned} \right\}$$

$$\text{where } E_{n,n+1}^{\text{Hy}} = 0.0136 z^2 \left(\frac{1}{n^2} - \frac{1}{(n+1)^2} \right), \text{ and} \quad (\text{B19})$$

$$Y(n, P_n) = y_0^n + y_1^n P_n + y_2^n P_n^2. \quad (\text{B20})$$

For the $n = 2, 3$, and 4 shells, the coefficients Y are given by

Table B1

n	Y_0^n	Y_1^n	Y_2^n
2	0.511	0.116	- 0.00689
3	0.400	0.0228	0.000596
4	0.230	0.00844	0.000488

The Gaunt factors are given by

$$g_{nn'} = 0.19 \left(1 + 0.9 \left\{ 1 + \frac{n'(n' - n)}{20} \left[1 + \left(1 - \frac{2}{Z} \right) \right] x_{nn'} \right\} \right. \\ \left. \exp(x_{nn'}) E_1(x_{nn'}) \right) \quad (B21)$$

where Z is the nuclear charge and $x_{nn'} = E_{nn'}/T$

For $\Delta n = 0$ transitions, we write the oscillator strengths, energies, and Gaunt factors in the form

$$f_{nn} = a_{nn} + b_{nn}/Z \quad (B22)$$

$$E_{nn} = \epsilon_{nn} Z^{\alpha_{nn}} \text{ (keV)} \quad (B23)$$

$$g_{nn} = C_{nn} + 0.276 \exp(x_{nn}) E_1(x_{nn}) \quad (B24)$$

$$C_{nn} = \begin{cases} d_{nn} \left(1 - \frac{\gamma_{nn}}{Z-1} \right) & Z \neq 1 \\ \frac{0.06}{1+x_{nn}} \left(x_{nn}^{1/2} - 2 \right) & Z = 1 \text{ (neutrals)} \end{cases} \quad (B25)$$

These values represent weighted averages over the possible allowed $\Delta n = 0$ transitions, and represent both individual LS coupling calculations at low-Z and jj transitions for high-Z. The coefficients a_{nn} , b_{nn} , ϵ_{nn} , α_{nn} , d_{nn} , and γ_{nn} are given for the transitions of interest in Tables B2 and B3.

TABLE B2

Ground State	a_{nn}	b_{nn}	ϵ_{nn} (keV)	α_{nn}	d_{nn}	γ_{nn}
$1s^2 2s$	-.02	2.0	2.04×10^{-3}	1.0	1.2	.54
$1s^2 2s^2$	-.01	4.33	4.49×10^{-3}	.93	.91	.77
$1s^2 2s^2 2p$	-.04	4.68	6.80×10^{-3}	.86	.89	.58
$1s^2 2s^2 2p^2$	.04	3.6	8.16×10^{-3}	.80	.92	.57
$1s^2 2s^2 2p^3$	-.01	2.85	6.80×10^{-3}	.87	.86	.41
$1s^2 2s^2 2p^4$	-.01	2.4	1.06×10^{-2}	.77	.87	.63
$1s^2 2s^2 2p^5$	.01	1.3	1.31×10^{-2}	.77	.85	.66
$1s^2 2s^2 2p^6$	0	0	0	1	0	0
$1s^2 2s^2 2p^6 3s$	.01	10.5	2.30×10^{-3}	.99	.72	.97
$1s^2 2s^2 2p^6 3s^2$	.10	20.0	3.88×10^{-3}	.90	.78	.96
$1s^2 2s^2 2p^6 3s^2 3p$	.25	16.4	5.71×10^{-3}	.83	.76	.88
$1s^2 2s^2 2p^6 3s^2 3p^2$	.17	24.7	5.44×10^{-3}	.87	.78	.86
$1s^2 2s^2 2p^6 3s^2 3p^3$	.08	34.1	8.16×10^{-3}	.77	.75	.87
$1s^2 2s^2 2p^6 3s^2 3p^4$	-.02	44.8	6.80×10^{-3}	.82	.70	.85
$1s^2 2s^2 2p^6 3s^2 3p^5$	-.14	56.8	8.30×10^{-3}	.79	.68	.83
$1s^2 2s^2 2p^6 3s^2 3p^6$	-.27	70.3	4.32×10^{-3}	1.06	.65	.86
$(1s^2 2s^2 2p^6 3s^2 3p^6) 3d$	-.29	68.6	5.11×10^{-3}	1.03	.65	.8
$3d^2$	-.30	65.8	6.00×10^{-3}	1.00	.70	.8
$3d^3$	-.30	61.9	7.08×10^{-3}	.97	.70	.8
$3d^4$	-.29	56.9	8.12×10^{-3}	.94	.70	.8
$3d^5$	-.27	50.7	9.69×10^{-3}	.91	.70	.8
$3d^6$	-.24	45.5	1.13×10^{-2}	.88	.70	.8
$3d^7$	-.20	34.4	1.37×10^{-2}	.85	.70	.8
$3d^8$	-.14	24.2	1.49×10^{-2}	.83	.70	.8
$3d^9$	-.08	12.8	1.71×10^{-2}	.80	.70	.8

TABLE B3*

Ground State [†]	a _{nn}	b _{nn}	ε _{nn} (keV)	α _{nn}
4s	.97	-25.8	1.52 × 10 ⁻⁵	2.46
4s ²	1.96	-53.1	1.93 × 10 ⁻⁵	2.40
4p	1.92	-28.1	5.62 × 10 ⁻⁵	2.14
4p ²	1.89	-2.97	1.20 × 10 ⁻⁴	1.96
4p ³	1.86	23.0	2.13 × 10 ⁻⁴	1.83
4p ⁴	1.83	50.3	3.34 × 10 ⁻⁴	1.72
4p ⁵	1.78	79.1	4.66 × 10 ⁻⁴	1.64
4p ⁶	1.73	109.2	6.66 × 10 ⁻⁴	1.57
4d	1.41	141.7	9.10 × 10 ⁻⁴	1.49
4d ²	1.05	176.0	1.25 × 10 ⁻³	1.41
4d ³	.674	213.9	1.69 × 10 ⁻³	1.34
4d ⁴	.261	256.6	1.98 × 10 ⁻³	1.30
4d ⁵	-.167	299.6	3.03 × 10 ⁻³	1.19
4d ⁶	-.637	348.2	3.92 × 10 ⁻³	1.13
4d ⁷	-1.14	400.5	5.19 × 10 ⁻³	1.06
4d ⁸	-1.67	456.6	6.40 × 10 ⁻³	1.01
4d ⁹	-2.26	518.1	8.05 × 10 ⁻³	.95
4d ¹⁰	-2.88	584.0	9.80 × 10 ⁻³	.91
4f	-2.90	571.9	1.08 × 10 ⁻²	.89
4f ²	-2.83	550.7	1.19 × 10 ⁻²	.87
4f ³	-2.72	524.9	1.32 × 10 ⁻²	.85
4f ⁴	-2.61	496.8	1.47 × 10 ⁻²	.83

*We rather arbitrarily choose d_{nn} = .70, γ_{nn} = .8 for all Δn = 0 transitions within the n = 4 shell.

†In addition to a core of 1s²2s²2p⁶3s²3p⁶3d¹⁰.

TABLE B3 (con't)

Ground State	a_{nn}	b_{nn}	ϵ_{nn} (keV)	α_{nn}
$4f^5$	-2.45	463.4	1.59×10^{-2}	.82
$4f^6$	-2.27	427.0	1.81×10^{-2}	.80
$4f^7$	-2.05	385.3	1.92×10^{-2}	.78
$4f^8$	-1.81	339.8	2.10×10^{-2}	.76
$4f^9$	-1.55	291.3	2.33×10^{-2}	.74
$4f^{10}$	-1.25	237.4	2.57×10^{-2}	.72
$4f^{11}$	-.94	181.3	2.82×10^{-2}	.70
$4f^{12}$	-.63	122.9	3.10×10^{-2}	.68
$4f^{13}$	-.31	62.2	3.43×10^{-3}	.66

APPENDIX C: Sensitivity of the Calculation

We have arbitrarily changed the rate coefficients by factors of two in order to assess the sensitivity of our calculation to the uncertainties in the atomic physics. The ionization states in a low-density plasma are determined by balancing the collisional ionization rate and the dielectronic recombination rate. Except for nearly stripped ions the radiative recombination is unimportant, also the radiation is dominated by line radiation. The contributions due to $\Delta n = 0$ and $\Delta n \neq 0$ are generally of comparable magnitude. Consequently, calculations for the radiated power and the mean charge state are most sensitive to ionization and dielectronic recombination rates. In addition the accuracy of the radiated power is almost directly proportional to the errors in the excitation rates. Figures C1 and C2 show a comparison of our "standard" radiation and $\langle Z \rangle$ calculations with calculations in which the collisional ionization and dielectronic recombination rates were multiplied by factors of 2 and 1/2.

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Figure Captions for Appendix C.

Fig. C1 (a) Molybdenum emission with the dielectronic recombination rate multiplied by 2 and 1/2. (The solid curve shows the normal calculation.

(b) Molybdenum emission with the collisional ionization rate multiplied by 2 and 1/2.

(c) $\langle Z \rangle$ for Molybdenum when the collisional ionization rate and dielectronic recombination rate are varied by factors of 2.

Fig. C2 (a) Tungsten emission with the dielectronic recombination rate multiplied by 2 and 1/2. (The solid curve shows the normal calculation.

(b) Tungsten emission with the collisional ionization rate multiplied by 2 and 1/2.

(c) $\langle Z \rangle$ for Tungsten when the collisional ionization rate and dielectronic recombination rate are varied by factors of 2.

Fig. C1

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Fig. C2