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ELECTRON IMPACT EXCITATION CROSS SECTIONS IN F-LIKE SELENIUM

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Cross sections for excitation induced by electron collision between low-lying $1s^22s^22p^5$ and $1s^22s2p^6$ states of F-like selenium and from these states to singly excited states with the excited electron occupying the *M* shell have been calculated by relativistic distorted-wave Born procedures. The GRASP[2] code was used for the atomic structure calculations. The continuum orbitals for the construction of continuum states were computed in the distorted-wave approximation, in which the distorted-wave potential used was the spherically averaged potential of the nucleus plus the potential of the bound electrons of the bound state. The cross sections for excitations were computed first by a 133-level multiconfiguration Dirac–Fock (MCDF) configuration expansion and then by a 279-level MCDF configuration expansion. The latter procedure, which also took into account contributions from all the participating singly excited *N*-shell states, was found to be necessary for improved accuracy. The cross section data should be a useful reference in the development of x-ray lasers and other related fields involving highly stripped ions.

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CONTENTS

INTRODUCTION

Electron impact excitation cross sections of highly stripped ions are needed in developing lasers in the extreme-ultraviolet (XUV) and soft x-ray regimes, in astrophysics, and in the study of inertial confinement fusion and other laboratory-produced plasmas. The first successful demonstration of a colloidal excitation soft x-ray laser was reported in 1985 [1, 2]. The resulting plasmas contained neon-like selenium ions in which population inversion was achieved between the 3*p* and 3*s* levels, leading to the observation of amplification of the 206.38 and 209.78 Å line emission. Since a decade ago, laboratory x-ray lasers have been studied by researchers worldwide. Soft x-ray laser schemes have been extrapolated to wavelengths as short as 43.18 Å in Ni-like W and 35.6 Å in Ni-like Au [3]. Cobalt-like laser lines were observed in Ta and Yb experiments [4]. One perplexing consequence of the observation of Co-like analog lasers is the absence of F-like lasers in Ne-like x-ray laser plasmas. The absence of any measurable gain on F-like lines is currently a mystery [5, 6]. Electron impact excitation cross sections for F-like selenium ions have been calculated by Hagelstein [5] using the relativistic distorted-wave Born (RDWB) method without exchange potentials, and by Sampson et al. [7] using the RDWB method with Dirac–Fock–Slater (DFS) potentials, which are energy independent in the evaluation of continuum orbitals. The atomic structure of both these calculations was obtained by a 113-level multiconfiguration Dirac–Fock (MCDF) configuration expansion.

The present calculation was also based on RDWB electron impact excitation procedures and a MCDF treatment of the bound electrons. Most of the theory and procedures for these calculations were described in detail in Ref. [8], except that some modifications have been made in order to adapt the atomic structure code GRASP^2 [9], which has some merits in numerical stability and accuracy.

In this paper we present more details of our analyses and more comprehensive results than those included in the short paper published earlier [10], which was confined to selected transitions from the ground state only. To compare our results with previous data, we have done calculations using almost identical approximations, such as a fictitious configuration with the same fractional occupation numbers. The continuum orbitals have been calculated with and without exchange potentials, and it was found that exchange potentials have some influence on the cross sections. Hence, the energy-dependent local semiclassical exchange (SCE) [11, 12] potential was used in all the calculations for the principal tabulation (Table V). Comparisons of the results have also been made for single excitation from the three lowest-lying levels to the *M* shell by (a) a 113-level MCDF configuration expansion which includes contributions from only the singly excited M shell states and (b) a 279-level MCDF configuration expansion which includes both the M and N shell states. These investigations have revealed that the more elaborate 279-level calculation is necessary, especially for excitation to the high-lying levels because configurations with M- and N-shell excitations have holes in the $2s$–$2p$ subshells and hence overlapping energy levels.

Atomic Structure

The atomic structure code GRASP^2, which is based on MCDF theory and intermediate coupling, is applied to the present relativistic bound state calculations. Atomic orbitals are taken to be four-component spinors. Multiconfiguration self-consistent-field (SCF) calculations are based on the Dirac–Coulomb Hamiltonian. The nuclear potential is modeled as a spherically symmetric distribution of nuclear charge. The one-body operator is based upon the Dirac kinetic-energy operator. The transverse photon interaction is added to the two-body operator. The calculations are performed perturbatively in the atomic structure section. In addition to the nonrelativistic Coulomb interaction, the electron undergoes relativistic interactions with the target nucleus and bound electrons, such as spin–orbit, spin–spin, and spin–other–orbit interactions. The Dirac Hamiltonian H_D which adequately describes the relativistic interaction [13, 14] is given by

$$H_D = c\boldsymbol{\alpha} \cdot \mathbf{p} + (\beta - 1)c^2 + V(r), \qquad (1)$$

where $c \sim 137.036$ is the speed of light in atomic units, and $\boldsymbol{\alpha}$, β are the usual Dirac matrices.

In the quantum electrodynamics (QED) picture, the Møller interaction in the Lorentz gauge for the photon propagator for bound–free and free–free electron interactions is [15]

$$H_M(1, 2) = \frac{1}{r_{12}}(1 - \boldsymbol{\alpha_1} \cdot \boldsymbol{\alpha_2})\exp(i\omega r_{12}), \qquad (2)$$

where ω is the wave number of the virtual photon exchanged between the two electrons. The generalized Breit interaction in the Coulomb gauge for the photon propagator in the context of the QED picture is

$$H_B(1, 2) = -(\boldsymbol{\alpha_1} \cdot \boldsymbol{\alpha_2})\frac{\exp(i\omega r_{12})}{r_{12}} + (\boldsymbol{\alpha_1} \cdot \boldsymbol{\nabla_1})(\boldsymbol{\alpha_2} \cdot \boldsymbol{\nabla_2})\frac{\exp(i\omega r_{12}) - 1}{\omega^2 r_{12}}. \qquad (3)$$

Using a local potential, the above-mentioned two gauges are indeed equal in their matrix element contributions. As to a nonlocal potential, the pictures of the two gauges in QED are considerably more complex and not very clear, although both contain the entire lowest-order Feynman diagram. The nuclear potential is derived from the Fermi charge distribution [16], for which the nuclear volume effect is considered. The "normal mass effect" and the "specific mass shift" due to nuclear motion corrections [13] and the vacuum polarization potential of Fullerton and Rinker [17, 18] are calculated via perturbation theory (that is, added to the matrix elements of the Dirac–Coulomb Hamiltonian prior to diagonalizing the resulting matrix). The self-energy is estimated by interpolation of the screened hydrogenic self-energy [19]. With the addition of the transverse photon interaction, the mixing coefficients may be somewhat changed. However, in the collision dynamics section, we exclude Møller scattering because the incident energy ($<10^5$ eV) was found to be insufficiently high to make the Møller interaction between the incident electron and bound electrons significant.

GRASP^2 is based on a completely new SCF algorithm adapted from procedures developed and extensively used by Fischer [20]. Extensive testing has revealed that great gains have been made in numerical stability, efficiency, and accuracy, when GRASP^2 is compared with its predecessors. All the present atomic structure data were obtained from the GRASP^2 code including bound-state orbitals, angular coefficients, and other required radial functions. All these functions were transformed to the new hybrid grid using a well-tested cubic spline interpolation.

The level designations up to $n = 3$ are given in Table I. Some minor errors in Table I of Ref. [5] have been corrected. In Table II we compare the values of the resonance transition energies obtained by different ways. The entries of "Present1" were obtained by the 113-level MCDF configuration expansion (referred to as mode A), 113 being the total number of energy levels of the ground and singly excited M shell states. The entries of "Present2" were obtained with the 279-level MCDF configuration expansion (referred to as mode B), where 279 is the total number of energy levels of the ground and singly excited M or N shell states. Because of the overlapping energy levels in this expansion, some of the singly excited N shell states are among the lowest 113 levels. However, the 113 levels listed for this expansion are still the three lowest-lying levels plus those with the singly excited M shell states; that is, they are the same as those listed in the 113-level MCDF configuration expansion. The relaxation effect is partly included in the "Present2" calculations. The difference in transition energies between mode A and mode B calculations is small. The largest difference is about 0.85 eV, corresponding to the resonance transition to level number 68. The entries labeled "Hagel" show the corresponding relativistic values of Hagelstein [5]. These values were obtained using a mean configuration in determining the central potential used in calculating the radial wave functions. The Breit interaction was included in his calculations only in the limit $\omega = 0$. Hagelstein used large-scale configuration interaction (CI) to catch most of the correlation effects (orbital relaxation), wherein calculations for the state $2s^22p^5\ ^2P_{1/2}$ were revised to bring about agreement with the extrapolated results of Edlén [21]. The entries labeled "Samp" by Sampson et al. [7] were also determined with a mean configuration. This work was somewhat similar to that of Hagelstein, but effects of the finite nuclear charge, retardation and generalized Breit interaction, vacuum polarization, and self-energy QED were included. The calculations of Sampson et al. [7] differ from ours on two points: (a) the present results which used the GRASP^2 code were obtained with a more accurate MCDF potential to determine the radial wave functions instead of a mean configuration as assumed by them in determining the central potential used in calculating the radial wave functions, and (b) relaxation effects ignored in their calculations were partly included in ours. Point (a) resulted in the energies of Sampson et al. [7] being generally higher than the present values by about 1 eV. Point (b), on the other hand, caused their results to be generally lower than the present calculations by about 1 eV. Thus the present results are accidentally in good agreement with those of Sampson et al. [7] except for some high-lying excited levels, where the discrepancies may go up to 1 eV. The present results are in good agreement with Hagelstein's values for the high-lying excited levels, but for the low-lying levels the discrepancies are generally about 1 eV. This may be due to less correlation effect (orbital relaxation) being included in our calculations.

In Table III we tabulate the theoretical and experimental values of transition energies and theoretical oscillator strengths by various authors for some of the x-ray transitions. For transition energies ΔE, the entries "Present2" were obtained by the 279-level MCDF configuration expansion, and the entries "Hagel" [5] and "Samp" [7] are theoretical values while the entries "Gord" [22] and "Burk" [23] are experimental values. The energy for the transition 2–5 is 1461.6 eV in the "Gord" entry instead of 1461.2 eV as cited in Ref. [7]. For oscillator strengths, the entries labeled "PresentC" in the first column are values obtained with the "Coulomb gauge," which in the nonrelativistic limit corresponds to the velocity form [13, 24]. The entries "PresentB" in the second column are values obtained with the "Babushkin gauge," which in the nonrelativistic limit corresponds to the length form. The oscillator strengths for both gauges were calculated by the 279-level MCDF configuration expansion (mode B). These oscillator strengths have also been calculated by the 113-level MCDF configuration expansion (mode A), but they are not shown in the Table because of space limitation. The oscillator strengths in the two gauges calculated using mode B are generally in better agreement than those calculated using mode A, and so the quality of the wave functions calculated using mode B should be better. The agreement for oscillator strengths between the two gauges in Table III is generally very good unless their values are extremely small ($<$0.001). This good agreement provides evidence that the wave functions obtained by the 279-level MCDF configuration expansion using the GRASP^2 code are very good. More broadly, the agreement of transition energies among various theoretical and experimental values is good for almost all of the transitions. In addition, except for some transitions to very high-lying states or those whose oscillator strengths are smaller than 0.001, the present oscillator strengths are in very good agreement with those calculated by Sampson et al. [7]. In many cases, Hagelstein's [5] oscillator strength in Table III lies between the values of the two gauges of the present calculations. However, for the transitions 2–5, 2–25, and 3–74, large differences exist. The oscillator strengths for transitions 2–64 and 2–94 in Tables III–V of Ref. [5] are not in accordance with those of Tables X–XII in that reference. In the present Table III, those oscillator strengths which are smaller than 10^{-4} are set equal to zero.

Outline of Collision Theory

The RDWB procedures used in the present calculations were given in Ref. [8]. Here, we only restate some main points to establish convention and notation. It is convenient to express the relativistic cross section $\sigma_{if}(\epsilon)$ for the transition $i \rightarrow f$ in terms of the collision strength $\Omega_{if}(\epsilon)$ by the relation

$$\sigma_{if}(\epsilon) = \frac{\pi a_0^2}{k_i^2 g_i}\,\Omega_{if}(\epsilon), \tag{4}$$

where the subscripts i and f refer to the initial and final states, a_0 is the Bohr radius, k_i is the relativistic wave number of the impact electron, and $g_i = [J_i] = 2J_i + 1$ is the statistical weight of the initial state of the N-electron target ion. The relation between the relativistic wave quantum number k of the impact electron and its relativistic momentum p and kinetic energy ϵ (in a.u.) is

$$k^2 = \frac{p^2 a_0^2}{\hbar^2} = \epsilon\left[2 + \frac{\epsilon}{c^2}\right], \tag{5}$$

wherein c is the speed of light in a.u. The total collision strength is computed by summing over the partial collision strengths, which are computed from the transition matrix T. T can be expressed in terms of the reactance matrix K. For highly charged ions of interest here, the elements of K are small, so that the weak-coupling approximation made in the RDWB method gives a good treatment. After applying the factorization method proposed by Bar-Shalom et al. [25] to the RDWB model by Sampson et al. [26], the final expression obtained for the collision strength Ω_{if} can be written as

$$\Omega_{if} = 8 \sum B \cdot Q, \tag{6}$$

where the sum is over all the target configuration state functions (CSF) included in the calculation and over the rank of the tensor products in the angular parts. B in Eq. (6) depends only on the properties of the target; Q in Eq. (6) contains the radial scattering matrix elements and is obtained by summation over initial and final orbitals and total angular momenta of the free electron within them. Therefore, Eq. (6) can be called the factorization form of RDWB theory, which enables fast calculations for electron impact excitation.

The direct part of the distorted potentials $V'(r)$ for calculating the continuum orbitals are the spherically averaged potentials of the nucleus plus the bound electrons of the bound state. The exchange potentials $V^{ex}(r)$ are chosen to be in the semiclassical exchange approximation [8, 12] and are local, energy-dependent potentials:

$$V^{ex}(r) = \tfrac{1}{2}\,[V'(r) - \epsilon][(1 + \delta^2)^{1/2} - 1], \tag{7}$$

where

$$\delta^2 = \frac{4\pi\rho(r)}{[V'(r) - \epsilon]^2}\,. \tag{8}$$

Here, ϵ is the free electron kinetic energy in atomic units. The potentials used in calculating the orbitals of the impact and scattered electrons for a certain transition differed only because of their different free-electron energies. The finite nuclear charge $Z(r)$, which differs from ordinary Z only for small r, is chosen to be the Fermi charge distribution [16] and can be obtained from the GRASP^2 code [9, 13].

Fictitious orbital occupation numbers in conjunction with the configuration given in (9) are used in the present calculation of continuum orbitals if no special mention is given. This configuration,

$$1s_{1/2}^{2.0}2s_{1/2}^{1.9}2p_{1/2}^{1.9}2p_{3/2}^{2.7}3s_{1/2}^{0.04}3p_{1/2}^{0.04}3p_{3/2}^{0.04}3d_{3/2}^{0.04}3d_{5/2}^{0.04}$$
$$4s_{1/2}^{0.04}4p_{1/2}^{0.04}4p_{3/2}^{0.04}4d_{3/2}^{0.04}4d_{5/2}^{0.04}4f_{5/2}^{0.05}4f_{7/2}^{0.05}, \tag{9}$$

is sometimes called a mean configuration. In the configuration so characterized, half an electron is excited. The original reason for using a mean configuration with a fictitious occupation number [5, 7] is to make all bound and free orbitals orthogonal. From tests mentioned in Ref. [5] as well as made by us, it may be concluded that there is little influence on the F-like selenium ion when different fictitious occupation numbers are used. Here, the fictitious occupation numbers are used solely to determine the spherically averaged Dirac–Fock central field potential for free orbitals. In our procedures, since the orbitals of the free electron so calculated are not orthogonal to those of the bound electrons obtained with the earlier-mentioned choice of potential, it is necessary to make some modifications in calculating the exchange matrix elements of the reaction matrix [12].

Cross Section Calculation and Discussion

We tabulate the cross sections in units of cm^2 for the 2–2 transitions and the 2–3 excitation transitions from the lowest three states, $2s^22p^5\ ^2P_{3/2}$, $^2P_{1/2}$, and $2s2p^6S_{1/2}$, respectively, in Table IV at electron impact energy 1000 eV above threshold. Results in Table IV were obtained using the 113-level MCDF configuration expansion. The entries "PresentO" were obtained using the 113-level calculation for which the continuum orbitals were computed without the exchange potential, and the distorted-wave potential used was the spherically averaged potential of the nucleus plus the potential due to the bound electrons of the bound state. Also, the fictitious mean configuration given below was used in determining the potential in the calculation of free electron orbitals:

$$1s_{1/2}^{2.0}2s_{1/2}^{1.27}2p_{1/2}^{1.27}2p_{3/2}^{3.82}3s_{1/2}^{0.128}3p_{1/2}^{0.128}3p_{3/2}^{0.128}3d_{3/2}^{0.128}3d_{5/2}^{0.128}. \tag{10}$$

This configuration is the same as that in Eq. (2.1) of Ref. [5], except that occupation numbers 0.127 in that equation were all replaced by 0.128. The above choice of occupation numbers gives 6.36 electrons in the L shell and 0.64 electrons in the M shell, which is not far from a 50%–50% split in the active electron. The approximations made here were kept almost the same as those in Ref. [5] in order to make the comparison between the two sets of results as meaningful as possible. The entries "PresentS" were obtained with the same approximations as the entries "PresentO," except that the SCE potential was added in "PresentS." By direct comparison of "PresentO" and "PresentS" we can gauge the influence of the exchange potential on the final values of the cross sections. The entries "Hagel" are results calculated by Hagelstein [5] using his RDWB code. The entries "Samp" are the results calculated by Sampson et al. [7]. Detailed comparisons among the above-mentioned four groups of entries will be given in the following two paragraphs.

From Table IV, we can observe the following for transitions from level 1: (1) Comparisons of the entries "PresentO" and "PresentS," later referred to as "Comparison A," reveal generally very good agreement with each other. This indicates that the exchange potential has only a little influence on the calculation. Most of the discrepancies are less than 1%. The largest discrepancy is nearly 2% for the transition 1–77. (2) "Comparison B" is between the entries "PresentS" and "Samp." There is generally very good agreement. However, some differences exist especially for transitions 1–67, 1–76, 1–78, 1–79, 1–80, 1–88, 1–91, 1–94, 1–99, 1–107, 1–109, 1–110, 1–111, 1–112, and 1–113, all of which have small collision strengths ($<10^{-3}$

or even $<10^{-4}$). The largest three discrepancies are 41% for transition 1–99, 59% for 1–109, and 76% for 1–113. (3) "Comparison C" refers to the comparisons of the entries "PresentO" and "Hagel." Here, the agreement is often very poor. This conclusion was also drawn by Sampson et al. [7]. About half of all the transitions have discrepancies of more than 10%. About one-third of all the transitions have discrepancies greater than 30%. For transitions from level 1 to levels 18, 22, 23, 24, 61, 62, 74, 77, 82, 83, 84, 102, 105, 112, and 113, the discrepancies are about 100% or even higher. For transition 1–62, the difference is about a factor of 5. This is the largest discrepancy in this comparison mode. Paradoxically, however, some of the transitions which have large differences in "Comparison B" are in good agreement or have smaller discrepancies in "Comparison C." This may be a consequence of the fact that the atomic structures used in the three calculational codes are somewhat different from one another.

In Table IV, we have also made comparisons in the same three modes for transitions from levels 2 and 3 to higher levels. For transitions from level 2, "Comparison A" yields the same conclusion as before. In "Comparison B," the following transitions have large discrepancies (percentage is given in parentheses if $>20\%$): transition from level 2 to levels 6, 13(26%), 29, 30, 36(21%), 70, 71(20%), 81, 85, 87, 91, 109(46%), 111, and 112(60%). "Comparison C" also reveals that about half of all the transitions have discrepancies greater than 10%. Nearly one-fifth of all the transitions have discrepancies of more than 100%. For the transitions 2–81, 2–83, 2–87, the differences run into several orders of magnitude.

For transitions from level 3, "Comparison A" again yields the same conclusion. As for "Comparison B," the conclusion is very different from those in the same comparison for transitions from levels 1 and 2, respectively. For transitions from level 3 to levels 4–58 (except levels 7, 13, 14, 19, 21, 24, 33, 56), and levels 63 and 64, the differences are vast (about a few factors). Once again, most of the collision strengths for these transitions are small ($<10^{-4}$). These differences are attributed to the different atomic structures used and will be analyzed in more detail below. For transitions from level 3 to levels 59–113 (except levels 63 and 64), the agreement is fairly good because the cross sections for these transitions are large. "Comparison C" also shows that in about half of all the transitions the discrepancies are very much larger than those in the previous two comparisons. There are 13 transitions whose differences are of several orders of magnitude. They are the transitions from level 3 to levels 29, 32, 35, 37, 42, 43, 47, 49, 52, 54, 55, 56, and 57.

A detailed investigation reveals that good agreement in transition energies and absorption oscillator strengths may lead to good agreement of their corresponding cross sections. Oscillator strengths are more likely to be in disagreement if they are exceedingly small. For half of the transitions from level 3, the agreement in cross sections is poor because the corresponding oscillator strengths for these transitions are very small and are also greatly in disagreement. This trend also applies to "Comparison C" between "PresentO" and "Hagel." For example, there is a 22% difference for transition 2–5 between the results of the "PresentO" and the "Hagel" entries, because the difference between their absorption oscillator strengths for this transition is 25%. This suggests that the bound orbital wave functions may play a crucial role in the calculation. For transitions with large oscillator strengths (>0.010), the agreement for cross sections among the results of the present calculations, Hagelstein [5], and Sampson et al. [7] is generally good. One reason for the differences in "Comparison C" is that possibly some inadequate approximations are made in the collision dynamics section of Ref. [5]. For example, the large summation cutoff in Ref. [5] in the product of the expansion coefficients as well as the limitation to no more than 30 partial collision strengths might have affected the computed total collision strengths. Also, Hagelstein [5] might have used a different spherically averaged potential in calculating the continuum orbitals in contrast to that used for the bound orbitals. If so, the continuum orbitals would not be orthogonal to the bound orbitals in his calculations and an additional correction would have been necessary when calculating the exchange collision matrix elements (but such a correction was not made). However, the main cause of the discrepancies in "Comparison C" as well as in "Comparison B" is most likely the different atomic structures used in the calculations, as discussed above.

Strong correlation effects have been known for the F-like selenium ion for configurations $2s2p^6$ and $2s^22p^5$. These are exhibited not only in the discrepancies in the energy levels, but also in the gauge dependence of the transition rates from the ground configuration $2s^22p^5$. This is especially so for the F-like selenium ion because the gauge dependence of its dipole transition rate is unusually large. This indicates that while the calculated energies are in good agreement with experiment, the configuration set used for correlation is still unbalanced, even though improvements have been made. Further correlation needs to be included to obtain more accurate transition rates. Accuracy in energy is not a good criterion to ensure a highly correlated wave function. There are other properties which may be very sensitive to parts of the wave function but to which the total energy is not sensitive.

In Table V, the cross sections are tabulated at five different impact electron energies. The approximations and the exchange potentials used in these calculations were the same as those in entries "PresentS" in Table IV except that the atomic structure was obtained with the 279-level MCDF configuration expansion, which includes the ground and all singly excited MCDF states in both the *M* and *N* shells. The fictitious mean configuration given in (9), in which exactly half an electron is excited, was used in determining the potential required in the calculation of the free electron orbitals. If comparisons are made between cross sections of "PresentS" in Table IV and those in Table V at electron impact energy 1000 eV above threshold, there are quite a few transitions whose discrepancies are more than 10%: for example, level 1 to levels 99, 105, 106; level 2 to levels 13, 83, 109, 110, 113; level 3 to levels 8, 25, 26, 34–36, 45, 48, 50–53. This demonstrates the necessity of the more elaborate calculation with the 279-level MCDF configuration expansion in order to achieve higher accuracy and more reliable results.

Our results for cross sections are expected to be reliable and accurate because elaborate atomic structure and collision dynamics were used in the calculations. It is hoped that the present sets of data in Table V by the 279-level MCDF configuration expansion will be a useful reference in the development of x-ray lasers and other fields involving highly stripped ions.

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EXPLANATION OF TABLES

TABLE I. Level Designations

Level	Index number for the 113 states including the three lowest-lying states and the singly excited M shell states of F-like selenium in order of increasing energy.
Configuration	(jj-coupling) configuration: p means $p_{3/2}$ and p* means $p_{1/2}$, etc.; for brevity, filled subshells are omitted except in the case of configurations with an empty $2s$ shell.
J2	Twice the total angular momentum quantum number.

TABLE II. Comparison of Resonance Transition Energies from Various Calculations

Level	Level designations keyed to the index number in Table I.
J	Total angular momentum quantum number.
ΔE	Energy of transition from the ground state (in eV).
Present1	Present 113-level MCDF configuration expansion calculation.
Present2	Present 279-level MCDF configuration expansion calculation.
Hagel	Relativistic values calculated by Hagelstein [5].
Samp	Relativistic values calculated by Sampson et al. [7].

TABLE III. Comparison of Transition Energies and Oscillator Strengths from Various Calculations and Experiments

Transition	Initial–final level designations using the level numbers of Table I.
J_f	Total angular momentum of the final level.
ΔE	Transition energy (in eV).
Present2	Value from the present 279-level MCDF configuration expansion calculation.
Hagel	Theoretical value from Hagelstein [5].
Samp	Theoretical value from Sampson et al. [7].
Gord	Experimental value from Gordon et al. [22].
Burk	Experimental value from Burkhalter et al. [23].
f value	Excitation oscillator strength (dimensionless).
PresentC	Value calculated using the Coulomb gauge.
PresentB	Value calculated using the Babushkin gauge.
Hagel	Value calculated by Hagelstein [5].
Samp	Value calculated by Sampson et al. [7].

TABLE IV. Comparison of Electron Impact Excitation Cross Sections from the Present 113-Level Calculation with Results from Other Works

This Table lists electron impact excitation cross sections (in cm^2) for all 2–2 transitions and 2–3 transitions from the states $2s^22p^5\ ^2P_{3/2}$, $^2P_{1/2}$, and $2s2p^6\ ^2S_{1/2}$ in F-like selenium calculated by the 113-level MCDF configuration expansion mode. Values are tabulated at electron impact energy 1000 eV above threshold. 4.792[−21] means 4.792×10^{-21}.

I	Initial level according to the number designation in Table I.
F	Final level according to the number designation in Table I.
PresentO	Present 113-level MCDF configuration expansion calculation, but with the continuum orbitals without the exchange potential.
PresentS	Results obtained with the same approximations as the entries "PresentO," except that the SCE exchange potential was added.
Hagel	Values calculated by Hagelstein [5] using his RDWB code.
Samp	Values calculated by Sampson et al. [7] at an electron energy 1016.8 eV above threshold, which is slightly larger than 1000 eV chosen for the present calculation.

TABLE V. Electron Impact Excitation Cross Sections Calculated by the 279-Level MCDF Configuration Expansion

This Table lists electron impact excitation cross sections (in cm^2) for all 2–2 transitions and 2–3 transitions from the states $2s^22p^5\ ^2P_{3/2}$, $^2P_{1/2}$, and $2s2p^6\ ^2S_{1/2}$ in F-like selenium calculated by the 279-level MCDF configuration expansion mode. Values are tabulated at electron impact energies 200, 500, 1000, 2000, and 4000 eV above threshold. Other approximations used were the same as in "PresentS" in Table IV. 2.638[−20] means 2.638×10^{-20}.

I	Initial level according to the number designation in Table I.
F	Final level according to the number designation in Table I.

TABLE I. Level Designations

See page 100 for Explanation of Tables

Level	Configuration	J2	Level	Configuration	J2	Level	Configuration	J2
1	$[2p^3]_{3/2}$	3	39	$[2p^2]_2 3d$	5	77	$[2s2p^*]_1 3s$	1
2	$[2p^*]_{1/2}$	1	40	$[2p^2]_0 3d^*$	3	78	$[2s2p^3]_1 3p$	1
3	$[2s]_{1/2}$	1	41	$[2p^2]_0 3d$	5	79	$[2s2p^*]_0 3p^*$	1
4	$[2p^2]_2 3s$	5	42	$[2p^* 2p^3]_1 3d^*$	1	80	$[2s2p^*]_0 3p$	3
5	$[2p^2]_2 3s$	3	43	$[2p^* 2p^3]_1 3d^*$	3	81	$[2s2p^3]_2 3d^*$	1
6	$[2p^2]_0 3s$	1	44	$[2p^* 2p^3]_1 3d$	7	82	$[2s2p^3]_2 3d^*$	3
7	$[2p^* 2p^3]_1 3s$	3	45	$[2s^2 2p^4]_0 3p^*$	1	83	$[2s2p^3]_2 3d$	9
8	$[2p^* 2p^3]_1 3s$	1	46	$[2s^2 2p^4]_0 3p$	3	84	$[2s2p^3]_2 3d^*$	5
9	$[2p^2]_2 3p^*$	3	47	$[2p^* 2p^3]_1 3d$	5	85	$[2s2p^3]_2 3d^*$	7
10	$[2p^2]_0 3p^*$	5	48	$[2p^* 2p^3]_1 3d^*$	5	86	$[2s2p^3]_2 3d$	5
11	$[2p^* 2p^3]_2 3s$	5	49	$[2p^* 2p^3]_1 3d$	3	87	$[2s2p^3]_2 3d$	7
12	$[2p^* 2p^3]_2 3s$	3	50	$[2p^* 2p^3]_2 3d^*$	7	88	$[2s2p^*]_1 3p^*$	3
13	$[2p^2]_2 3p$	1	51	$[2p^* 2p^3]_2 3d$	9	89	$[2s2p^3]_2 3d$	3
14	$[2p^2]_2 3p$	5	52	$[2p^* 2p^3]_2 3d$	5	90	$[2s2p^3]_2 3d$	1
15	$[2p^2]_2 3p$	7	53	$[2p^* 2p^3]_2 3d^*$	1	91	$[2s2p^*]_1 3p$	1
16	$[2p^2]_0 3p^*$	1	54	$[2p^* 2p^3]_2 3d$	7	92	$[2s2p^*]_1 3p$	5
17	$[2p^2]_2 3p$	3	55	$[2p^* 2p^3]_2 3d^*$	3	93	$[2s2p^3]_1 3d^*$	5
18	$[2p^2]_0 3p$	3	56	$[2p^* 2p^3]_2 3d^*$	5	94	$[2s2p^*]_1 3p$	3
19	$[2p^* 2p^3]_1 3p^*$	1	57	$[2p^* 2p^3]_2 3d$	3	95	$[2s2p^3]_1 3d^*$	3
20	$[2p^* 2p^3]_1 3p^*$	3	58	$[2p^* 2p^3]_2 3d^*$	1	96	$[2s2p^3]_1 3d^*$	1
21	$[2p^* 2p^3]_1 3p$	5	59	$[2s2p^3]_2 3s$	5	97	$[2s2p^3]_1 3d$	7
22	$[2p^* 2p^3]_2 3p^*$	5	60	$[2s2p^3]_2 3s$	3	98	$[2s2p^3]_1 3d$	5
23	$[2p^* 2p^3]_1 3p$	1	61	$[2s2p^3]_1 3s$	3	99	$[2s2p^*]_1 3p^*$	1
24	$[2p^* 2p^3]_1 3p$	3	62	$[2s2p^3]_1 3s$	1	100	$[2s2p^3]_1 3d$	3
25	$[2s^2 2p^4]_0 3s$	1	63	$[2s^2 2p^4]_0 3d$	5	101	$[2s2p^*]_0 3d$	5
26	$[2p^* 2p^3]_2 3p$	7	64	$[2s^2 2p^4]_0 3d^*$	3	102	$[2s2p^*]_0 3d^*$	3
27	$[2p^* 2p^3]_2 3p$	3	65	$[2s2p^3]_2 3p^*$	3	103	$[2s2p^*]_1 3d^*$	5
28	$[2p^2]_2 3d^*$	5	66	$[2s2p^3]_2 3p^*$	5	104	$[2s2p^*]_1 3d$	7
29	$[2p^2]_2 3d^*$	3	67	$[2s2p^*]_0 3s$	1	105	$[2s2p^*]_1 3d$	3
30	$[2p^2]_2 3d$	7	68	$[2s2p^3]_2 3p$	7	106	$[2s2p^*]_1 3d^*$	1
31	$[2p^* 2p^3]_2 3p$	5	69	$[2s2p^3]_2 3p$	3	107	$[2s2p^*]_1 3d$	5
32	$[2p^2]_2 3d^*$	1	70	$[2s2p^3]_2 3p$	5	108	$[2s2p^*]_1 3d^*$	3
33	$[2p^* 2p^3]_2 3p^*$	3	71	$[2s2p^3]_2 3p$	1	109	$[2p^{*2} 2p^4]_0 3s$	1
34	$[2p^2]_2 3d$	9	72	$[2s2p^3]_1 3p^*$	3	110	$[2p^{*2} 2p^4]_0 3p^*$	1
35	$[2p^2]_2 3d^*$	7	73	$[2s2p^3]_1 3p^*$	1	111	$[2p^{*2} 2p^4]_0 3p$	3
36	$[2p^2]_2 3d$	1	74	$[2s2p^*]_1 3s$	3	112	$[2p^{*2} 2p^4]_0 3d^*$	3
37	$[2p^2]_2 3d$	3	75	$[2s2p^3]_1 3p$	5	113	$[2p^{*2} 2p^4]_0 3d$	5
38	$[2p^* 2p^3]_2 3p$	1	76	$[2s2p^3]_1 3p$	3			

TABLE II. Comparison of Resonance Transition Energies from Various Calculations
See page 100 for Explanation of Tables

Level	J	ΔE(eV) Present1	Present2	Hagel	Samp	Level	J	ΔE(eV) Present1	Present2	Hagel	Samp
1	3/2	0	0	0	0	58	1/2	1684.02	1684.54	1685.8	1684.7
2	1/2	42.74	42.87	42.8	42.8	59	5/2	1687.42	1688.23	1688.9	1687.8
3	1/2	212.95	213.20	212.4	213.0	60	3/2	1695.75	1696.45	1697.1	1696.1
4	5/2	1498.59	1499.34	1500.5	1499.2	61	3/2	1712.02	1712.74	1713.4	1712.4
5	3/2	1503.28	1504.02	1505.2	1504.0	62	1/2	1712.47	1713.21	1713.9	1712.8
6	1/2	1517.84	1518.61	1519.7	1518.4	63	5/2	1716.84	1717.59	1718.7	1717.6
7	3/2	1539.26	1539.99	1541.4	1540.0	64	3/2	1721.04	1721.63	1722.9	1721.8
8	1/2	1542.97	1543.69	1545.1	1543.8	65	3/2	1731.74	1732.56	1733.0	1732.1
9	3/2	1543.52	1544.27	1545.3	1544.1	66	5/2	1735.18	1736.01	1736.4	1735.6
10	5/2	1545.34	1546.10	1547.1	1546.0	67	1/2	1735.73	1736.45	1737.2	1736.2
11	5/2	1552.12	1552.87	1554.2	1552.8	68	7/2	1742.97	1743.82	1744.2	1743.3
12	3/2	1553.49	1554.23	1555.5	1554.2	69	3/2	1745.59	1746.41	1746.8	1746.0
13	1/2	1554.19	1554.91	1555.9	1554.7	70	5/2	1748.26	1749.06	1749.5	1748.7
14	5/2	1555.02	1555.77	1556.7	1555.6	71	1/2	1753.14	1753.93	1754.4	1753.5
15	7/2	1555.79	1556.57	1557.5	1556.4	72	3/2	1755.55	1756.37	1756.8	1755.9
16	1/2	1564.34	1565.14	1566.0	1564.9	73	1/2	1756.70	1757.42	1757.9	1756.9
17	3/2	1570.16	1570.85	1571.9	1570.8	74	3/2	1765.33	1766.12	1766.8	1765.6
18	3/2	1575.66	1576.43	1577.4	1576.2	75	5/2	1765.46	1766.29	1766.7	1765.8
19	1/2	1582.86	1583.60	1584.8	1583.5	76	3/2	1766.38	1767.18	1767.7	1766.8
20	3/2	1587.84	1588.56	1589.7	1588.5	77	1/2	1768.84	1769.58	1770.2	1769.1
21	5/2	1594.94	1595.69	1596.8	1595.6	78	1/2	1772.29	1773.03	1773.6	1772.6
22	5/2	1597.29	1598.07	1599.1	1597.9	79	1/2	1784.23	1784.88	1785.4	1784.5
23	1/2	1598.02	1598.74	1599.9	1598.7	80	3/2	1789.82	1790.62	1791.2	1790.3
24	3/2	1598.63	1599.38	1600.5	1599.4	81	1/2	1794.74	1795.57	1796.0	1795.1
25	1/2	1600.64	1601.39	1602.8	1601.4	82	3/2	1797.02	1797.83	1798.3	1797.4
26	7/2	1607.60	1608.37	1609.4	1608.2	83	9/2	1799.20	1799.87	1800.4	1799.5
27	3/2	1608.43	1609.16	1610.2	1609.0	84	5/2	1800.40	1801.15	1801.6	1800.8
28	5/2	1610.68	1611.39	1612.4	1611.4	85	7/2	1800.65	1801.34	1801.9	1801.0
29	3/2	1611.07	1611.81	1612.8	1611.8	86	5/2	1806.44	1807.16	1807.6	1806.8
30	7/2	1611.77	1612.46	1613.5	1612.4	87	7/2	1807.76	1808.48	1808.9	1808.1
31	5/2	1611.96	1612.74	1613.8	1612.6	88	3/2	1809.98	1810.81	1811.3	1810.1
32	1/2	1612.71	1613.47	1614.4	1613.4	89	3/2	1811.06	1811.73	1812.3	1811.4
33	3/2	1613.95	1614.34	1615.4	1614.6	90	1/2	1818.98	1819.56	1820.2	1819.3
34	9/2	1615.12	1615.82	1616.8	1615.8	91	1/2	1819.53	1820.35	1820.8	1819.7
35	7/2	1616.04	1616.76	1617.7	1616.7	92	5/2	1820.76	1821.57	1822.1	1820.9
36	1/2	1620.73	1621.48	1622.4	1621.2	93	5/2	1823.12	1823.80	1824.4	1823.5
37	3/2	1624.39	1625.10	1626.1	1625.1	94	3/2	1823.43	1824.29	1824.7	1823.6
38	1/2	1626.59	1627.13	1628.3	1627.3	95	3/2	1824.08	1824.77	1825.3	1824.4
39	5/2	1627.66	1628.33	1629.3	1628.4	96	1/2	1824.56	1825.19	1825.7	1824.9
40	3/2	1633.63	1634.35	1635.3	1634.3	97	7/2	1824.69	1825.38	1825.9	1825.0
41	5/2	1636.24	1636.95	1637.9	1636.9	98	5/2	1824.75	1825.46	1826.0	1825.1
42	1/2	1649.13	1649.82	1651.1	1649.9	99	1/2	1826.94	1827.16	1827.7	1826.9
43	3/2	1653.16	1653.87	1655.1	1653.9	100	3/2	1831.54	1832.11	1832.8	1831.9
44	7/2	1653.95	1654.64	1655.8	1654.7	101	5/2	1848.56	1849.25	1849.9	1849.0
45	1/2	1655.23	1655.74	1656.9	1656.0	102	3/2	1851.84	1852.38	1853.1	1852.2
46	3/2	1657.00	1657.76	1658.9	1657.7	103	5/2	1877.40	1877.99	1878.7	1877.6
47	5/2	1657.78	1658.48	1659.6	1658.5	104	7/2	1878.53	1879.09	1879.7	1878.7
48	5/2	1659.38	1660.07	1661.2	1660.1	105	3/2	1880.52	1880.94	1881.7	1880.5
49	3/2	1659.98	1660.70	1661.8	1660.7	106	1/2	1883.94	1884.15	1884.1	1883.9
50	7/2	1664.50	1665.19	1666.4	1665.2	107	5/2	1883.53	1884.16	1885.7	1883.7
51	9/2	1666.23	1666.90	1668.0	1666.9	108	3/2	1884.18	1884.70	1885.4	1884.3
52	5/2	1669.44	1670.19	1671.2	1670.1	109	1/2	1934.84	1935.60	1935.5	1934.7
53	1/2	1669.52	1670.27	1671.3	1669.6	110	1/2	1977.17	1978.05	1977.7	1977.0
54	7/2	1672.28	1673.03	1674.0	1672.9	111	3/2	1987.87	1988.75	1988.5	1987.7
55	3/2	1672.72	1673.31	1674.4	1673.4	112	3/2	2042.89	2043.42	2043.4	2042.7
56	5/2	1674.21	1674.78	1675.9	1674.9	113	5/2	2045.14	2045.68	2045.6	2044.9
57	3/2	1681.53	1682.07	1683.3	1682.3						

TABLE III. Comparison of Transition Energies and Oscillator Strengths from Various Calculations and Experiments

See page 100 for Explanation of Tables

Transition	$\Delta E(eV)$					f value			
	Present2	Hagel	Samp	Gord	Burk	PresentC	PresentB	Hagel	Samp
J_f=1/2									
1-6	1518.61	1519.7	1518.4	1520.1		0.0133	0.0132	0.013	0.0128
1-8	1543.69	1545.1	1543.8	1544.7	1546.1	0.0134	0.0138	0.014	0.0127
1-25	1601.39	1602.8	1601.4			0.0011	0.0010		0.0011
1-32	1613.47	1614.4	1613.4			0.0019	0.0020		0.0020
1-36	1621.48	1622.4	1621.2	1623.4	1617.3	0.0832	0.0880	0.088	0.0845
1-42	1649.82	1651.1	1649.9			0.0006	0.0006		0.0006
1-53	1670.27	1671.3	1669.6	1671.6	1669.4	0.2100	0.2225	0.220	0.2028
1-58	1684.54	1685.8	1684.7			0.0478	0.0503	0.052	0.0549
1-71	1753.93	1754.4	1753.5			0.0060	0.0062		0.0059
1-73	1757.42	1757.9	1756.9	1756.9		0.0617	0.0626	0.063	0.0647
1-78	1773.03	1773.6	1772.6			0.0023	0.0021		0.0027
1-79	1784.88	1785.4	1784.4			0.0040	0.0036		0.0047
1-91	1820.35	1820.8	1819.7			0.0006	0.0005		0.0006
1-99	1827.16	1827.2	1826.9			0.0002	0.0001		0.0006
1-109	1935.60	1935.5	1934.7			0.0002	0.0002		0.0003
J_f=3/2									
1-5	1504.02	1505.2	1504.0	1505.2	1505.0	0.0658	0.0681	0.067	0.0618
1-7	1539.99	1541.4	1540.0	1541.7	1541.1	0.0169	0.0175	0.017	0.0160
1-12	1554.23	1555.5	1554.2			0.0042	0.0043		0.0040
1-29	1611.81	1612.8	1611.8			0.0001	0.0001		0.0001
1-37	1625.10	1626.1	1525.1	1626.4	1623.1	0.1733	0.1828	0.185	0.1739
1-40	1634.35	1635.3	1634.3			0.1252	0.1313	0.135	0.1312
1-43	1653.87	1655.1	1553.9	1656.0		0.0117	0.0122	0.012	0.0117
1-49	1660.70	1661.8	1660.7			0.0034	0.0036		0.0031
1-55	1673.31	1674.4	1673.5	1675.4		0.4618	0.4878	0.497	0.4801
1-57	1682.07	1683.3	1682.3	1682.7		0.1247	0.1284	0.130	0.1307
1-64	1721.63	1722.9	1721.8			0.0002	0.0001		0.0003
1-65	1732.56	1733.0	1732.1			0.0034	0.0034		0.0033
1-69	1746.41	1746.8	1746.0			0.0479	0.0496		0.0472
1-72	1756.37	1756.8	1755.9	1756.9		0.0569	0.0580	0.058	0.0588
1-76	1767.18	1767.7	1766.8			0.0202	0.0195	0.019	0.0210
1-80	1790.62	1791.2	1790.3			0.0001	0.0001		0.0001
1-88	1810.81	1811.3	1810.1			0.0059	0.0054		0.0064
1-94	1824.29	1824.7	1823.6			0.0063	0.0052		0.0072
1-112	2043.42	2043.4	2042.7			0.0001	0.0001		0.0002
J_f=5/2									
1-4	1499.34	1500.0	1499.2		1501.0	0.0095	0.0100		0.0091
1-11	1552.87	1554.2	1552.8	1554.1	1554.9	0.0471	0.0494	0.049	0.0448
1-28	1611.39	1612.4	1611.4			0.0000	0.0000		0.0001
1-39	1628.33	1629.3	1628.4	1629.2	1627.5	0.3716	0.3834	0.381	0.3688
1-41	1636.95	1637.9	1636.9		1637.6	0.2225	0.2291	0.243	0.2390
1-47	1658.48	1659.6	1658.5	1660.8	1658.7	0.1107	0.1145	0.106	0.1030
1-48	1660.07	1661.2	1660.1			0.1896	0.1956	0.205	0.1971
1-52	1670.19	1671.2	1670.1			0.0328	0.0333	0.033	0.0329
1-56	1674.78	1675.9	1674.9	1675.4	1672.8	0.7280	0.7488	0.773	0.7766
1-63	1717.59	1718.7	1717.6			0.0043	0.0044		0.0048
1-66	1736.01	1736.4	1735.6	1736.9		0.0461	0.0457	0.045	0.0459
1-70	1749.06	1749.5	1748.7	1749.9		0.0693	0.0690	0.069	0.0700
1-75	1766.29	1766.8	1765.8	1767.4		0.0626	0.0630	0.062	0.0640
1-92	1821.57	1822.1	1820.9	1821.1		0.0183	0.0189	0.018	0.0192
1-113	2045.68	2045.6	2044.9			0.0011	0.0010		0.0020
J_f=1/2									
2-6	1475.74	1476.9	1475.7			0.0003	0.0004		0.0002
2-8	1500.82	1502.3	1501.1	1501.2		0.0425	0.0440	0.043	0.0400
2-25	1558.52	1560.0	1558.6	1560.5		0.0384	0.0390	0.089	0.0369
2-32	1570.60	1571.6	1570.6			0.0006	0.0006		0.0006
2-36	1578.61	1579.6	1578.5			0.0001	0.0001		0.0001
2-42	1606.95	1608.3	1607.2			0.0018	0.0018		0.0017
2-53	1627.40	1628.5	1626.9	1626.4		0.0428	0.0455	0.045	0.0472
2-58	1641.67	1643.0	1642.0	1642.6		0.7172	0.7587	0.770	0.7323

TABLE III. Comparison of Transition Energies and Oscillator Strengths from Various Calculations and Experiments

See page 100 for Explanation of Tables

	$\Delta E(eV)$					f value			
Transition	Present2	Hagel	Samp	Gord	Burk	PresentC	PresentB	Hagel	Samp
2-71	1711.06	1711.6	1710.8			0.0053	0.0060		0.0048
2-73	1714.55	1715.1	1714.2			0.0000	0.0000		0.0000
2-78	1730.16	1730.8	1729.9			0.0007	0.0007		0.0007
2-79	1742.01	1742.6	1741.8	1742.3		0.0745	0.0772	0.078	0.0768
2-91	1777.48	1778.0	1777.0	1774.2		0.0767	0.0738	0.073	0.0819
2-99	1784.29	1784.9	1784.2			0.0002	0.0005		0.0000
2-109	1892.73	1892.7	1892.0			0.0005	0.0005		0.0007
J_f=3/2									
2-5	1461.15	1462.4	1461.3	1461.6		0.0008	0.0008	0.001	0.0007
2-7	1497.12	1498.6	1497.3			0.0025	0.0026		0.0023
2-12	1511.36	1512.7	1511.5	1512.5	1511.5	0.0881	0.0917	0.089	0.0839
2-29	1568.94	1570.0	1569.0			0.0030	0.0032		0.0027
2-37	1582.23	1583.3	1582.3			0.0113	0.0113	0.011	0.0103
2-40	1591.48	1592.5	1591.5			0.0012	0.0011		0.0015
2-43	1611.00	1612.3	1611.2			0.0157	0.0164	0.017	0.0154
2-49	1617.83	1619.0	1618.0	1619.0		0.0773	0.0801	0.078	0.0745
2-55	1630.44	1631.6	1630.7	1629.2		0.1648	0.1753	0.178	0.1705
2-57	1639.20	1640.5	1639.5	1638.9		0.9380	0.9654	0.984	0.9684
2-64	1678.76	1680.1	1679.1	1680.2		0.9249	0.9555	0.979	0.9764
2-65	1689.69	1690.2	1689.3			0.0000	0.0000		0.0000
2-69	1703.54	1704.0	1703.2			0.0000	0.0001		0.0000
2-72	1713.50	1714.0	1713.2			0.0125	0.0125	0.012	0.0122
2-76	1724.31	1724.9	1724.0	1724.4		0.0259	0.0261	0.026	0.0250
2-80	1747.75	1748.4	1747.5	1749.9		0.0715	0.0719	0.072	0.0716
2-88	1767.94	1768.5	1767.4	1767.4		0.0832	0.0858	0.085	0.0854
2-94	1781.42	1781.9	1780.9	1780.6		0.0759	0.0737	0.073	0.0796
2-112	2000.55	2000.6	1999.9			0.0021	0.0020		0.0033
J_f=1/2									
3-13	1341.71	1343.5	1341.0			0.0000	0.0000		0.0000
3-16	1351.94	1353.6	1351.2			0.0003	0.0004		0.0001
3-19	1370.40	1372.4	1369.8			0.0000	0.0000		0.0000
3-23	1385.54	1387.5	1384.9			0.0000	0.0000		0.0000
3-38	1413.93	1415.9	1413.5			0.0021	0.0026		0.0016
3-45	1442.54	1444.5	1442.2			0.0001	0.0000		0.0002
3-62	1500.01	1501.5	1499.1			0.0391	0.0407	0.040	0.0360
3-67	1523.25	1524.8	1522.4			0.0321	0.0338	0.033	0.0298
3-77	1556.38	1557.8	1555.3			0.0018	0.0017	0.019	0.0017
3-81	1582.37	1583.6	1581.4			0.0002	0.0002		0.0002
3-90	1606.36	1607.8	1605.6			0.3094	0.3237	0.327	0.3054
3-96	1611.99	1613.3	1611.1			0.1750	0.1821	0.193	0.1842
3-106	1670.95	1672.7	1670.2			0.6432	0.6740	0.692	0.6774
3-110	1764.85	1765.3	1763.3			0.0560	0.0551	0.054	0.0575
J_f=3/2									
3-9	1331.07	1330.9	1330.4			0.0000	0.0001		0.0000
3-17	1357.65	1359.5	1357.1			0.0005	0.0005		0.0003
3-18	1363.23	1365.0	1362.5			0.0001	0.0002		0.0000
3-20	1375.36	1377.3	1374.7			0.0001	0.0003		0.0000
3-24	1386.18	1388.1	1385.6			0.0000	0.0000		0.0000
3-27	1395.96	1397.8	1395.3			0.0007	0.0011		0.0005
3-33	1401.14	1403.0	1400.9			0.0017	0.0018		0.0015
3-46	1444.56	1446.5	1443.9			0.0008	0.0011		0.0005
3-60	1483.25	1484.7	1482.4			0.0659	0.0690	0.068	0.0603
3-61	1499.54	1501.0	1498.7			0.0154	0.0165	0.016	0.0144
3-74	1552.92	1554.4	1551.8			0.0717	0.0742	0.033	0.0673
3-82	1584.63	1585.9	1583.6			0.0010	0.0011		0.0011
3-89	1598.53	1599.9	1597.7			0.1451	0.1516	0.155	0.1447
3-95	1611.57	1612.9	1610.7			0.0448	0.0462	0.046	0.0404
3-100	1618.91	1620.4	1618.1			0.5165	0.5407	0.552	0.5284
3-102	1639.18	1640.7	1638.5			0.6117	0.6388	0.653	0.6247
3-105	1667.74	1669.3	1666.8			0.5335	0.5614	0.546	0.5509
3-108	1671.50	1673.0	1670.6			0.3770	0.3943	0.445	0.4177
3-111	1775.55	1776.1	1774.0			0.1152	0.1136	0.112	0.1179

TABLE IV. Comparison of Electron Impact Excitation Cross Sections from the Present 113-Level Calculation with Results from Other Works

See page 100 for Explanation of Tables

I	F	PresentO	PresentS	Hagel	Samp
1	2	4.792[-21]	4.761[-21]		4.73[-21]
1	3	4.655[-20]	4.645[-20]		4.98[-20]
1	4	2.027[-22]	2.017[-22]	1.922[-22]	1.95[-22]
1	5	4.126[-22]	4.127[-22]	4.521[-22]	3.93[-22]
1	6	1.071[-22]	1.069[-22]	1.096[-22]	1.07[-22]
1	7	1.257[-22]	1.256[-22]	1.323[-22]	1.21[-22]
1	8	8.286[-23]	8.284[-23]	8.799[-23]	8.00[-23]
1	9	2.889[-22]	2.854[-22]	2.795[-22]	2.72[-22]
1	10	4.574[-22]	4.528[-22]	4.598[-22]	4.34[-22]
1	11	2.970[-22]	2.970[-22]	3.344[-22]	2.83[-22]
1	12	6.878[-23]	6.840[-23]	8.016[-23]	6.64[-23]
1	13	1.929[-22]	1.910[-22]	1.953[-22]	1.85[-22]
1	14	4.694[-22]	4.648[-22]	4.542[-22]	4.45[-22]
1	15	4.009[-22]	3.945[-22]	3.758[-22]	3.77[-22]
1	16	9.283[-23]	9.159[-23]	9.306[-23]	8.79[-23]
1	17	1.883[-21]	1.892[-21]	1.125[-21]	1.80[-21]
1	18	6.983[-22]	6.991[-22]	3.592[-22]	6.86[-22]
1	19	4.664[-23]	4.583[-23]	3.058[-22]	4.37[-23]
1	20	4.902[-22]	4.913[-22]	1.054[-21]	4.52[-22]
1	21	2.052[-22]	2.029[-22]	2.290[-22]	1.93[-22]
1	22	1.447[-22]	1.420[-22]	4.362[-22]	1.34[-22]
1	23	7.215[-23]	7.140[-23]	1.373[-22]	6.78[-23]
1	24	2.693[-22]	2.689[-22]	5.319[-22]	2.60[-22]
1	25	7.955[-24]	7.951[-24]	7.432[-24]	8.38[-24]
1	26	3.479[-22]	3.453[-22]	3.791[-22]	3.33[-22]
1	27	5.697[-22]	5.711[-22]	7.768[-22]	5.45[-22]
1	28	4.900[-22]	4.855[-22]	4.833[-22]	4.64[-22]
1	29	3.455[-22]	3.425[-22]	3.385[-22]	3.27[-22]
1	30	5.692[-22]	5.634[-22]	5.637[-22]	5.35[-22]
1	31	1.898[-22]	1.879[-22]	2.073[-22]	1.81[-22]
1	32	1.859[-22]	1.844[-22]	1.783[-22]	1.76[-22]
1	33	7.314[-21]	7.362[-21]	1.267[-20]	7.08[-21]
1	34	4.737[-22]	4.686[-22]	4.702[-22]	4.49[-22]
1	35	4.978[-22]	4.953[-22]	4.923[-22]	4.78[-22]
1	36	1.275[-21]	1.277[-21]	1.309[-21]	1.25[-21]
1	37	2.686[-21]	2.690[-21]	2.578[-21]	2.62[-21]
1	38	6.507[-23]	6.446[-23]	7.004[-23]	6.27[-23]
1	39	5.148[-21]	5.157[-21]	5.237[-21]	5.13[-21]
1	40	1.854[-21]	1.857[-21]	1.822[-21]	1.86[-21]
1	41	3.232[-21]	3.236[-21]	3.410[-21]	3.34[-21]
1	42	5.191[-23]	5.137[-23]	5.466[-23]	4.91[-23]
1	43	2.438[-22]	2.432[-22]	2.397[-22]	2.36[-22]
1	44	2.719[-22]	2.696[-22]	2.700[-22]	2.58[-22]
1	45	1.180[-23]	1.162[-23]	1.451[-23]	1.12[-23]
1	46	8.756[-24]	8.626[-24]	1.187[-23]	8.79[-24]
1	47	1.447[-21]	1.449[-21]	1.382[-21]	1.41[-21]
1	48	2.562[-21]	2.566[-21]	2.592[-21]	2.57[-21]
1	49	1.925[-22]	1.913[-22]	1.975[-22]	1.84[-22]
1	50	1.919[-22]	1.895[-22]	1.842[-22]	1.80[-22]
1	51	3.202[-22]	3.188[-22]	3.410[-22]	3.11[-22]
1	52	5.683[-22]	5.674[-22]	6.329[-22]	5.84[-22]
1	53	2.722[-21]	2.728[-21]	2.916[-21]	2.55[-21]
1	54	2.166[-22]	2.152[-22]	2.355[-22]	2.08[-22]
1	55	6.050[-21]	6.063[-21]	5.940[-21]	5.96[-21]
1	56	9.162[-21]	9.183[-21]	9.628[-21]	9.42[-21]
1	57	1.619[-21]	1.623[-21]	1.689[-21]	1.64[-21]
1	58	6.895[-22]	6.904[-22]	6.289[-22]	7.25[-22]
1	59	7.692[-23]	7.566[-23]	6.275[-23]	7.16[-23]
1	60	1.964[-21]	1.977[-21]	1.839[-21]	1.88[-21]

TABLE IV. Comparison of Electron Impact Excitation Cross Sections from the Present 113-Level Calculation with Results from Other Works

See page 100 for Explanation of Tables

I	F	PresentO	PresentS	Hagel	Samp
1	61	2.662[-21]	2.680[-21]	4.242[-21]	2.63[-21]
1	62	1.648[-23]	1.621[-23]	8.015[-23]	1.58[-23]
1	63	6.796[-23]	6.796[-23]	7.049[-23]	7.28[-23]
1	64	1.365[-23]	1.351[-23]	1.509[-23]	1.40[-23]
1	65	5.643[-23]	5.623[-23]	5.733[-23]	5.59[-23]
1	66	2.173[-22]	2.174[-22]	2.195[-22]	2.29[-22]
1	67	1.509[-24]	1.490[-24]	1.321[-23]	1.76[-24]
1	68	8.364[-23]	8.313[-23]	8.447[-23]	8.06[-23]
1	69	2.308[-22]	2.311[-22]	2.828[-22]	2.33[-22]
1	70	2.954[-22]	2.957[-22]	3.722[-22]	3.14[-22]
1	71	4.005[-23]	4.001[-23]	5.400[-23]	4.17[-23]
1	72	2.546[-22]	2.551[-22]	2.779[-22]	2.71[-22]
1	73	2.503[-22]	2.508[-22]	2.601[-22]	2.74[-22]
1	74	3.257[-22]	3.277[-22]	6.174[-22]	3.38[-22]
1	75	2.581[-22]	2.585[-22]	2.776[-22]	2.75[-22]
1	76	9.087[-23]	9.087[-23]	1.117[-22]	1.01[-22]
1	77	5.394[-24]	5.308[-24]	1.861[-23]	5.15[-24]
1	78	1.644[-23]	1.640[-23]	1.374[-23]	1.96[-23]
1	79	1.678[-23]	1.679[-23]	1.171[-23]	2.14[-23]
1	80	1.643[-24]	1.640[-24]	1.163[-24]	1.47[-24]
1	81	4.336[-23]	4.302[-23]	5.789[-23]	4.13[-23]
1	82	8.569[-23]	8.503[-23]	1.670[-22]	8.17[-23]
1	83	2.182[-22]	2.166[-22]	3.489[-22]	2.05[-22]
1	84	1.297[-22]	1.287[-22]	2.382[-22]	1.24[-22]
1	85	3.302[-22]	3.291[-22]	3.959[-22]	3.18[-22]
1	86	5.715[-22]	5.711[-22]	7.235[-22]	5.57[-22]
1	87	1.018[-21]	1.017[-21]	1.063[-21]	1.00[-21]
1	88	2.483[-23]	2.481[-23]	2.174[-23]	2.88[-23]
1	89	3.275[-22]	3.272[-22]	4.338[-22]	3.21[-22]
1	90	1.142[-22]	1.140[-22]	1.762[-22]	1.12[-22]
1	91	5.298[-24]	5.269[-24]	5.529[-24]	5.83[-24]
1	92	7.671[-23]	7.679[-23]	7.191[-23]	7.95[-23]
1	93	6.222[-22]	6.220[-22]	6.812[-22]	6.09[-22]
1	94	2.323[-23]	2.319[-23]	2.655[-23]	2.98[-23]
1	95	6.370[-22]	6.371[-22]	6.911[-22]	6.34[-22]
1	96	4.404[-22]	4.406[-22]	5.229[-22]	4.46[-22]
1	97	9.330[-22]	9.329[-22]	1.001[-21]	9.40[-22]
1	98	4.102[-22]	4.098[-22]	4.261[-22]	4.23[-22]
1	99	8.398[-24]	8.357[-24]	7.401[-24]	1.18[-23]
1	100	1.164[-22]	1.161[-22]	1.593[-22]	1.22[-22]
1	101	3.920[-24]	3.890[-24]	5.994[-23]	3.82[-24]
1	102	5.070[-23]	5.063[-23]	2.021[-22]	5.44[-23]
1	103	1.232[-22]	1.230[-22]	1.263[-22]	1.28[-22]
1	104	2.233[-22]	2.231[-22]	2.487[-22]	2.31[-22]
1	105	2.830[-23]	2.813[-23]	8.358[-23]	2.71[-23]
1	106	1.797[-23]	1.791[-23]	2.411[-23]	1.56[-23]
1	107	1.141[-22]	1.139[-22]	1.166[-22]	1.18[-22]
1	108	6.670[-23]	6.662[-23]	8.161[-23]	6.60[-23]
1	109	1.459[-24]	1.458[-24]	1.337[-24]	2.32[-24]
1	110	1.301[-24]	1.292[-24]	1.315[-24]	1.11[-24]
1	111	2.755[-24]	2.741[-24]	2.946[-24]	3.05[-24]
1	112	2.680[-24]	2.670[-24]	4.581[-24]	3.60[-24]
1	113	1.082[-23]	1.083[-23]	2.879[-23]	1.91[-23]
2	3	4.972[-20]	4.962[-20]		5.26[-20]
2	4	5.076[-24]	5.038[-24]	4.953[-24]	4.93[-24]
2	5	6.392[-24]	6.383[-24]	7.825[-24]	5.85[-24]
2	6	7.937[-24]	7.890[-24]	8.739[-24]	6.85[-24]

TABLE IV. Comparison of Electron Impact Excitation Cross Sections from the Present 113-Level Calculation with Results from Other Works

See page 100 for Explanation of Tables

I	F	PresentO	PresentS	Hagel	Samp
2	7	1.162[-22]	1.154[-22]	1.129[-22]	1.11[-22]
2	8	2.538[-22]	2.540[-22]	2.880[-22]	2.44[-22]
2	9	9.848[-24]	9.738[-24]	1.429[-23]	9.07[-24]
2	10	1.096[-23]	1.082[-23]	1.836[-23]	1.04[-23]
2	11	1.515[-22]	1.504[-22]	1.427[-22]	1.45[-22]
2	12	5.241[-22]	5.246[-22]	5.073[-22]	4.99[-22]
2	13	3.513[-23]	3.528[-23]	2.590[-23]	2.80[-23]
2	14	1.366[-23]	1.353[-23]	2.311[-23]	1.27[-23]
2	15	9.812[-24]	9.621[-24]	3.323[-23]	9.17[-24]
2	16	8.868[-24]	8.722[-24]	2.823[-23]	8.64[-24]
2	17	3.952[-23]	3.910[-23]	1.261[-22]	3.73[-23]
2	18	4.963[-23]	4.880[-23]	5.200[-23]	4.71[-23]
2	19	1.664[-22]	1.644[-22]	1.552[-22]	1.56[-22]
2	20	3.556[-22]	3.521[-22]	5.501[-22]	3.35[-22]
2	21	3.025[-22]	2.971[-22]	8.861[-22]	2.83[-22]
2	22	5.562[-22]	5.524[-22]	5.251[-22]	5.35[-22]
2	23	2.575[-22]	2.568[-22]	1.940[-22]	2.38[-22]
2	24	3.063[-22]	3.041[-22]	2.059[-21]	2.92[-22]
2	25	2.600[-22]	2.598[-22]	2.720[-22]	2.59[-22]
2	26	3.792[-22]	3.718[-22]	1.200[-21]	3.51[-22]
2	27	2.374[-22]	2.346[-22]	1.123[-21]	2.25[-22]
2	28	2.353[-23]	2.332[-23]	2.194[-23]	2.17[-23]
2	29	5.760[-23]	5.754[-23]	4.501[-23]	4.97[-23]
2	30	1.757[-23]	1.736[-23]	1.726[-23]	1.64[-23]
2	31	3.844[-22]	3.819[-22]	1.483[-21]	3.72[-22]
2	32	1.675[-23]	1.671[-23]	2.055[-23]	1.69[-23]
2	33	2.400[-22]	2.375[-22]	2.652[-22]	2.29[-22]
2	34	1.167[-23]	1.153[-23]	1.175[-23]	1.08[-23]
2	35	9.963[-24]	9.916[-24]	9.302[-24]	9.19[-24]
2	36	1.156[-23]	1.147[-23]	1.371[-23]	9.45[-24]
2	37	1.503[-22]	1.504[-22]	1.548[-22]	1.44[-22]
2	38	4.929[-21]	4.961[-21]	1.466[-21]	4.74[-21]
2	39	1.904[-23]	1.884[-23]	1.984[-23]	1.80[-23]
2	40	4.522[-23]	4.490[-23]	4.936[-23]	4.82[-23]
2	41	5.916[-23]	5.850[-23]	5.862[-23]	5.59[-23]
2	42	2.907[-22]	2.884[-22]	2.870[-22]	2.75[-22]
2	43	6.289[-22]	6.256[-22]	6.144[-22]	5.99[-22]
2	44	4.100[-22]	4.052[-22]	4.029[-22]	3.86[-22]
2	45	5.439[-21]	5.473[-21]	3.197[-21]	5.30[-21]
2	46	5.092[-22]	5.042[-22]	5.040[-22]	4.89[-22]
2	47	3.747[-22]	3.709[-22]	3.733[-22]	3.54[-22]
2	48	3.619[-22]	3.610[-22]	3.741[-22]	3.49[-22]
2	49	1.256[-21]	1.256[-21]	1.278[-21]	1.22[-21]
2	50	5.720[-22]	5.699[-22]	5.449[-22]	5.56[-22]
2	51	5.120[-22]	5.057[-22]	5.228[-22]	4.82[-22]
2	52	3.675[-22]	3.646[-22]	3.733[-22]	3.50[-22]
2	53	8.554[-22]	8.545[-22]	9.285[-22]	8.79[-22]
2	54	3.349[-22]	3.329[-22]	3.241[-22]	3.22[-22]
2	55	2.627[-21]	2.630[-21]	2.416[-21]	2.54[-21]
2	56	3.085[-22]	3.060[-22]	2.953[-22]	2.93[-22]
2	57	1.215[-20]	1.217[-20]	1.249[-20]	1.24[-20]
2	58	9.788[-21]	9.810[-21]	9.382[-21]	9.51[-21]
2	59	2.790[-24]	2.736[-24]	4.248[-23]	2.41[-24]
2	60	7.428[-24]	7.328[-24]	5.678[-23]	7.38[-24]
2	61	2.373[-23]	2.333[-23]	4.603[-23]	2.17[-23]
2	62	7.776[-22]	7.825[-22]	5.968[-22]	7.29[-22]
2	63	6.844[-22]	6.795[-22]	6.838[-22]	6.56[-22]
2	64	1.167[-20]	1.170[-20]	1.183[-20]	1.19[-20]
2	65	2.579[-24]	2.570[-24]	4.276[-24]	2.62[-24]

TABLE IV. Comparison of Electron Impact Excitation Cross Sections from the Present 113-Level Calculation with Results from Other Works

See page 100 for Explanation of Tables

I	F	PresentO	PresentS	Hagel	Samp
2	66	2.445[-24]	2.429[-24]	2.852[-24]	2.62[-24]
2	67	1.446[-21]	1.455[-21]	2.202[-21]	1.39[-21]
2	68	1.710[-24]	1.689[-24]	2.458[-24]	1.67[-24]
2	69	1.234[-23]	1.233[-23]	9.986[-24]	1.05[-23]
2	70	1.069[-24]	1.065[-24]	1.075[-24]	1.25[-24]
2	71	3.915[-23]	3.919[-23]	3.932[-23]	3.26[-23]
2	72	6.516[-23]	6.514[-23]	7.489[-23]	6.80[-23]
2	73	4.998[-24]	4.977[-24]	6.327[-24]	4.42[-24]
2	74	7.032[-23]	6.917[-23]	8.738[-23]	6.80[-23]
2	75	3.400[-23]	3.379[-23]	3.247[-23]	3.22[-23]
2	76	1.110[-22]	1.111[-22]	1.251[-22]	1.13[-22]
2	77	2.774[-21]	2.793[-21]	3.348[-21]	2.78[-21]
2	78	2.764[-23]	2.751[-23]	3.114[-23]	2.80[-23]
2	79	3.706[-22]	3.713[-22]	3.664[-22]	3.90[-22]
2	80	3.356[-22]	3.358[-22]	3.478[-22]	3.50[-22]
2	81	3.686[-25]	3.659[-25]	1.571[-22]	4.06[-25]
2	82	2.203[-24]	2.187[-24]	1.027[-22]	2.12[-24]
2	83	7.639[-27]	7.605[-27]	4.397[-25]	0.00[+00]
2	84	4.113[-24]	4.088[-24]	7.450[-23]	3.94[-24]
2	85	3.599[-24]	3.572[-24]	3.790[-23]	3.16[-24]
2	86	1.359[-23]	1.351[-23]	3.760[-23]	1.30[-23]
2	87	6.723[-25]	6.664[-25]	1.183[-23]	6.19[-25]
2	88	3.822[-22]	3.828[-22]	4.264[-22]	3.97[-22]
2	89	3.573[-23]	3.566[-23]	1.202[-22]	3.23[-22]
2	90	1.345[-23]	1.335[-23]	4.280[-23]	1.21[-23]
2	91	2.760[-22]	2.765[-22]	3.062[-22]	3.22[-22]
2	92	8.713[-23]	8.661[-23]	8.589[-23]	8.42[-23]
2	93	1.994[-22]	1.990[-22]	1.965[-22]	1.93[-22]
2	94	2.865[-22]	2.868[-22]	3.525[-22]	3.24[-22]
2	95	3.817[-23]	3.788[-23]	6.566[-23]	3.58[-23]
2	96	7.429[-24]	7.373[-24]	7.672[-24]	6.91[-24]
2	97	9.156[-23]	9.087[-23]	1.213[-22]	8.60[-23]
2	98	3.455[-22]	3.452[-22]	4.551[-22]	3.28[-22]
2	99	2.674[-23]	2.658[-23]	2.871[-23]	2.68[-23]
2	100	1.298[-22]	1.293[-22]	1.367[-22]	1.26[-22]
2	101	9.598[-22]	9.586[-22]	9.344[-22]	9.38[-22]
2	102	8.349[-22]	8.345[-22]	1.072[-21]	8.24[-22]
2	103	9.343[-22]	9.337[-22]	9.741[-22]	9.33[-22]
2	104	2.441[-22]	2.422[-22]	2.959[-22]	2.34[-22]
2	105	7.287[-22]	7.285[-22]	7.755[-22]	6.94[-22]
2	106	6.369[-23]	6.320[-23]	6.674[-23]	6.28[-23]
2	107	1.282[-21]	1.282[-21]	1.304[-21]	1.32[-21]
2	108	6.897[-22]	6.894[-22]	7.294[-22]	7.37[-22]
2	109	3.071[-24]	3.071[-24]	2.977[-24]	4.48[-24]
2	110	3.268[-24]	3.259[-24]	2.694[-24]	3.78[-24]
2	111	3.947[-24]	3.918[-24]	4.875[-24]	3.50[-24]
2	112	1.974[-23]	1.979[-23]	4.610[-23]	3.16[-23]
2	113	4.184[-24]	4.153[-24]	4.519[-24]	4.19[-24]
3	4	1.408[-24]	1.402[-24]	3.967[-24]	6.97[-25]
3	5	1.123[-24]	1.118[-24]	4.494[-24]	4.04[-25]
3	6	5.003[-24]	5.018[-24]	6.319[-24]	1.73[-24]
3	7	3.974[-25]	3.924[-25]	1.314[-24]	4.49[-25]
3	8	4.908[-25]	4.899[-25]	3.787[-25]	3.61[-25]
3	9	1.957[-24]	1.951[-24]	2.210[-24]	1.08[-24]
3	10	9.665[-25]	9.584[-25]	9.785[-25]	8.09[-25]
3	11	4.801[-24]	4.789[-24]	3.847[-24]	1.22[-24]
3	12	3.692[-24]	3.683[-24]	3.190[-24]	1.04[-24]

TABLE IV. Comparison of Electron Impact Excitation Cross Sections from the Present 113-Level Calculation with Results from Other Works

See page 100 for Explanation of Tables

I	F	PresentO	PresentS	Hagel	Samp
3	13	1.095[-24]	1.091[-24]	1.041[-24]	1.13[-24]
3	14	1.146[-24]	1.136[-24]	1.252[-24]	9.94[-25]
3	15	6.736[-25]	6.694[-25]	6.465[-25]	3.47[-25]
3	16	4.834[-24]	4.835[-24]	4.033[-24]	1.80[-24]
3	17	7.453[-24]	7.461[-24]	1.047[-23]	6.33[-24]
3	18	3.404[-24]	3.397[-24]	2.231[-24]	6.59[-25]
3	19	5.937[-25]	5.886[-25]	9.709[-25]	5.52[-25]
3	20	2.650[-24]	2.646[-24]	2.550[-24]	2.00[-24]
3	21	1.089[-24]	1.079[-24]	4.044[-24]	1.05[-24]
3	22	1.285[-24]	1.281[-24]	1.310[-24]	5.03[-25]
3	23	9.193[-25]	9.166[-25]	2.201[-24]	1.13[-24]
3	24	4.632[-25]	4.583[-25]	2.867[-24]	4.85[-25]
3	25	6.803[-24]	6.820[-24]	4.277[-24]	3.20[-24]
3	26	1.764[-24]	1.758[-24]	1.718[-24]	6.26[-25]
3	27	8.312[-24]	8.322[-24]	1.128[-23]	3.34[-24]
3	28	1.958[-24]	1.926[-24]	2.405[-24]	9.96[-25]
3	29	1.314[-24]	1.295[-24]	4.271[-23]	6.57[-25]
3	30	1.948[-24]	1.909[-24]	2.863[-24]	9.61[-25]
3	31	7.056[-25]	7.008[-25]	7.868[-25]	5.08[-25]
3	32	1.082[-24]	1.076[-24]	3.561[-23]	4.23[-25]
3	33	2.027[-23]	2.030[-23]	3.181[-23]	1.76[-23]
3	34	5.454[-26]	5.440[-26]	5.442[-26]	0.00[+00]
3	35	1.894[-25]	1.864[-25]	3.886[-24]	7.15[-26]
3	36	1.428[-23]	1.435[-23]	1.748[-23]	4.14[-24]
3	37	1.347[-24]	1.341[-24]	3.149[-23]	8.10[-25]
3	38	2.467[-23]	2.471[-23]	3.794[-23]	1.61[-23]
3	39	9.729[-25]	9.663[-25]	3.986[-23]	5.69[-25]
3	40	1.053[-23]	1.052[-23]	1.600[-23]	7.05[-24]
3	41	1.764[-23]	1.763[-23]	9.818[-23]	1.24[-23]
3	42	7.432[-25]	7.287[-25]	2.550[-21]	3.82[-25]
3	43	1.211[-24]	1.194[-24]	4.845[-21]	6.21[-25]
3	44	1.710[-24]	1.676[-24]	1.330[-21]	1.03[-24]
3	45	1.831[-24]	1.825[-24]	5.153[-24]	3.40[-24]
3	46	1.434[-23]	1.433[-23]	1.234[-23]	7.35[-24]
3	47	2.052[-24]	2.042[-24]	3.025[-21]	1.39[-24]
3	48	4.413[-24]	4.406[-24]	1.302[-23]	3.42[-24]
3	49	8.900[-25]	8.781[-25]	5.190[-22]	5.07[-25]
3	50	1.928[-25]	1.913[-25]	8.572[-25]	3.48[-26]
3	51	1.875[-25]	1.870[-25]	1.860[-25]	0.00[+00]
3	52	2.449[-24]	2.440[-24]	4.560[-23]	1.19[-24]
3	53	4.707[-23]	4.731[-23]	5.797[-23]	1.53[-23]
3	54	4.680[-25]	4.592[-25]	3.394[-23]	2.82[-25]
3	55	1.196[-24]	1.183[-24]	3.061[-23]	9.10[-25]
3	56	4.341[-24]	4.319[-24]	1.788[-22]	4.49[-24]
3	57	1.530[-24]	1.520[-24]	5.855[-22]	8.92[-25]
3	58	1.257[-23]	1.264[-23]	1.486[-22]	5.92[-24]
3	59	1.532[-22]	1.520[-22]	1.474[-22]	1.46[-22]
3	60	4.371[-22]	4.373[-22]	4.371[-22]	4.06[-22]
3	61	1.794[-22]	1.788[-22]	1.820[-22]	1.66[-22]
3	62	2.456[-22]	2.458[-22]	2.539[-22]	2.30[-22]
3	63	2.914[-23]	2.911[-23]	2.563[-23]	2.10[-23]
3	64	3.193[-23]	3.189[-23]	6.826[-23]	2.50[-23]
3	65	3.361[-22]	3.316[-22]	4.266[-22]	3.13[-22]
3	66	4.759[-22]	4.717[-22]	4.491[-22]	4.47[-22]
3	67	2.086[-22]	2.087[-22]	2.280[-22]	1.94[-22]
3	68	3.940[-22]	3.863[-22]	8.506[-22]	3.66[-22]
3	69	2.822[-22]	2.790[-22]	8.443[-22]	2.64[-22]
3	70	4.489[-22]	4.461[-22]	8.322[-22]	4.26[-22]
3	71	4.634[-22]	4.648[-22]	3.358[-22]	4.44[-22]

TABLE IV. Comparison of Electron Impact Excitation Cross Sections from the Present 113-Level Calculation with Results from Other Works

See page 100 for Explanation of Tables

I	F	PresentO	PresentS	Hagel	Samp
3	72	2.144[-22]	2.118[-22]	3.275[-22]	2.01[-22]
3	73	1.080[-21]	1.084[-21]	1.112[-21]	1.01[-21]
3	74	4.603[-22]	4.606[-22]	3.907[-22]	4.42[-22]
3	75	2.725[-22]	2.676[-22]	8.065[-22]	2.53[-22]
3	76	3.829[-22]	3.807[-22]	1.158[-21]	3.65[-22]
3	77	6.052[-23]	6.011[-23]	5.630[-23]	6.07[-23]
3	78	1.236[-21]	1.243[-21]	8.982[-22]	1.19[-21]
3	79	2.277[-21]	2.290[-21]	6.095[-22]	2.11[-21]
3	80	2.852[-22]	2.826[-22]	3.050[-22]	2.69[-22]
3	81	2.962[-22]	2.935[-22]	2.790[-22]	2.75[-22]
3	82	5.169[-22]	5.123[-22]	4.782[-22]	4.83[-22]
3	83	5.355[-22]	5.289[-22]	5.506[-22]	5.03[-22]
3	84	4.741[-22]	4.694[-22]	4.515[-22]	4.41[-22]
3	85	4.270[-22]	4.230[-22]	4.166[-22]	4.04[-22]
3	86	3.980[-22]	3.947[-22]	3.890[-22]	3.75[-22]
3	87	5.234[-22]	5.224[-22]	4.910[-22]	5.04[-22]
3	88	2.366[-22]	2.333[-22]	3.410[-22]	2.22[-22]
3	89	2.276[-21]	2.279[-21]	2.110[-21]	2.22[-21]
3	90	4.386[-21]	4.395[-21]	4.382[-21]	4.28[-21]
3	91	3.764[-22]	3.771[-22]	4.196[-22]	3.66[-22]
3	92	5.375[-22]	5.335[-22]	6.492[-22]	5.13[-22]
3	93	2.669[-22]	2.642[-22]	2.841[-22]	2.52[-22]
3	94	1.440[-22]	1.416[-22]	4.312[-22]	1.33[-22]
3	95	9.363[-22]	9.351[-22]	8.353[-22]	8.48[-22]
3	96	2.869[-21]	2.873[-21]	2.726[-21]	2.81[-21]
3	97	3.754[-22]	3.714[-22]	3.626[-22]	3.54[-22]
3	98	5.058[-22]	5.037[-22]	4.992[-22]	4.80[-22]
3	99	9.150[-21]	9.210[-21]	4.319[-21]	8.68[-21]
3	100	7.296[-21]	7.311[-21]	7.008[-21]	7.32[-21]
3	101	3.966[-22]	3.944[-22]	4.013[-22]	3.76[-22]
3	102	8.594[-21]	8.612[-21]	8.180[-21]	8.44[-21]
3	103	3.012[-22]	2.980[-22]	3.057[-22]	2.84[-22]
3	104	5.115[-22]	5.089[-22]	4.871[-22]	4.93[-22]
3	105	6.620[-21]	6.632[-21]	6.648[-21]	6.94[-21]
3	106	8.217[-21]	8.236[-21]	8.091[-21]	8.29[-21]
3	107	2.053[-22]	2.028[-22]	1.945[-22]	1.92[-22]
3	108	5.491[-21]	5.503[-21]	5.131[-21]	5.27[-21]
3	109	1.964[-21]	1.975[-21]	1.892[-21]	1.94[-21]
3	110	2.493[-22]	2.493[-22]	2.806[-22]	2.72[-22]
3	111	4.980[-22]	4.980[-22]	5.604[-22]	5.40[-22]
3	112	1.285[-21]	1.283[-21]	1.285[-21]	1.29[-21]
3	113	1.911[-21]	1.909[-21]	1.917[-21]	1.91[-21]

TABLE V. Electron Impact Excitation Cross Sections Calculated by the 279-Level MCDF Configuration Expansion

See page 100 for Explanation of Tables

I	F	200 eV	500 eV	1000 eV	2000 eV	4000 eV
1	2	2.638[-20]	1.063[-20]	4.806[-21]	2.032[-21]	8.594[-22]
1	3	1.176[-19]	7.359[-20]	4.725[-20]	2.928[-20]	1.762[-20]
1	4	3.548[-22]	2.798[-22]	2.040[-22]	1.336[-22]	8.768[-23]
1	5	3.939[-22]	4.055[-22]	4.216[-22]	4.390[-22]	4.349[-22]
1	6	1.350[-22]	1.211[-22]	1.083[-22]	9.687[-23]	8.701[-23]
1	7	1.484[-22]	1.372[-22]	1.277[-22]	1.192[-22]	1.100[-22]
1	8	8.426[-23]	8.352[-23]	8.423[-23]	8.546[-23]	8.327[-23]
1	9	5.858[-22]	4.355[-22]	2.877[-22]	1.544[-22]	7.107[-23]
1	10	8.224[-22]	6.378[-22]	4.545[-22]	2.835[-22]	1.650[-22]
1	11	2.991[-22]	2.995[-22]	3.038[-22]	3.088[-22]	2.996[-22]
1	12	1.155[-22]	9.219[-23]	6.882[-23]	4.714[-23]	3.273[-23]
1	13	3.592[-22]	2.764[-22]	1.937[-22]	1.163[-22]	6.379[-23]
1	14	8.377[-22]	6.525[-22]	4.680[-22]	2.950[-22]	1.740[-22]
1	15	8.429[-22]	6.153[-22]	3.962[-22]	2.045[-22]	8.988[-23]
1	16	1.864[-22]	1.384[-22]	9.170[-23]	5.022[-23]	2.457[-23]
1	17	2.577[-21]	2.249[-21]	1.863[-21]	1.396[-21]	9.384[-22]
1	18	1.067[-21]	8.817[-22]	6.815[-22]	4.685[-22]	2.905[-22]
1	19	1.012[-22]	7.322[-23]	4.610[-23]	2.238[-23]	8.512[-24]
1	20	7.281[-22]	6.084[-22]	4.769[-22]	3.332[-22]	2.094[-22]
1	21	3.889[-22]	2.963[-22]	2.042[-22]	1.193[-22]	6.331[-23]
1	22	3.193[-22]	2.294[-22]	1.424[-22]	6.636[-23]	2.248[-23]
1	23	1.316[-22]	1.018[-22]	7.190[-23]	4.392[-23]	2.478[-23]
1	24	4.113[-22]	3.438[-22]	2.711[-22]	1.935[-22]	1.270[-22]
1	25	1.024[-23]	9.119[-24]	8.081[-24]	7.156[-24]	6.360[-24]
1	26	5.306[-22]	4.414[-22]	3.490[-22]	2.548[-22]	1.759[-22]
1	27	9.384[-22]	7.887[-22]	6.222[-22]	4.376[-22]	2.761[-22]
1	28	1.150[-21]	8.095[-22]	4.909[-22]	2.250[-22]	7.939[-23]
1	29	8.037[-22]	5.673[-22]	3.457[-22]	1.602[-22]	5.808[-23]
1	30	1.383[-21]	9.624[-22]	5.706[-22]	2.473[-22]	7.537[-23]
1	31	3.360[-22]	2.619[-22]	1.879[-22]	1.185[-22]	7.031[-23]
1	32	4.154[-22]	2.965[-22]	1.850[-22]	9.170[-23]	3.982[-23]
1	33	9.415[-21]	8.291[-21]	6.923[-21]	5.214[-21]	3.495[-21]
1	34	1.120[-21]	7.839[-22]	4.733[-22]	2.194[-22]	8.348[-23]
1	35	9.092[-22]	6.991[-22]	4.991[-22]	3.204[-22]	1.973[-22]
1	36	1.560[-21]	1.424[-21]	1.274[-21]	1.093[-21]	8.951[-22]
1	37	3.230[-21]	2.972[-21]	2.682[-21]	2.319[-21]	1.905[-21]
1	38	1.118[-22]	8.760[-23]	6.317[-23]	4.001[-23]	2.372[-23]
1	39	5.832[-21]	5.538[-21]	5.169[-21]	4.618[-21]	3.878[-21]
1	40	2.184[-21]	2.011[-21]	1.820[-21]	1.581[-21]	1.307[-21]
1	41	3.780[-21]	3.481[-21]	3.148[-21]	2.734[-21]	2.261[-21]
1	42	1.179[-22]	8.367[-23]	5.178[-23]	2.543[-23]	1.116[-23]
1	43	3.700[-22]	3.047[-22]	2.408[-22]	1.808[-22]	1.348[-22]
1	44	6.098[-22]	4.362[-22]	2.728[-22]	1.348[-22]	5.657[-23]
1	45	2.285[-23]	1.674[-23]	1.070[-23]	5.281[-24]	2.009[-24]
1	46	1.861[-23]	1.371[-23]	8.907[-24]	4.630[-24]	2.040[-24]
1	47	1.779[-21]	1.660[-21]	1.520[-21]	1.340[-21]	1.119[-21]
1	48	2.858[-21]	2.686[-21]	2.477[-21]	2.200[-21]	1.848[-21]
1	49	3.871[-22]	2.885[-22]	1.945[-22]	1.129[-22]	6.298[-23]
1	50	4.661[-22]	3.240[-22]	1.911[-22]	8.146[-23]	2.391[-23]
1	51	5.491[-22]	4.345[-22]	3.230[-22]	2.192[-22]	1.419[-22]
1	52	8.706[-22]	7.268[-22]	5.833[-22]	4.461[-22]	3.377[-22]
1	53	3.037[-21]	2.910[-21]	2.732[-21]	2.464[-21]	2.087[-21]
1	54	4.179[-22]	3.144[-22]	2.162[-22]	1.306[-22]	7.549[-23]
1	55	6.535[-21]	6.292[-21]	5.935[-21]	5.376[-21]	4.567[-21]
1	56	9.562[-21]	9.254[-21]	8.779[-21]	8.006[-21]	6.844[-21]
1	57	1.764[-21]	1.672[-21]	1.555[-21]	1.393[-21]	1.179[-21]
1	58	7.954[-22]	7.306[-22]	6.567[-22]	5.684[-22]	4.700[-22]
1	59	1.765[-22]	1.253[-22]	7.650[-23]	3.497[-23]	1.156[-23]
1	60	2.497[-21]	2.224[-21]	1.885[-21]	1.448[-21]	9.919[-22]

TABLE V. Electron Impact Excitation Cross Sections Calculated by the 279-Level MCDF Configuration Expansion

See page 100 for Explanation of Tables

I	F	200 eV	500 eV	1000 eV	2000 eV	4000 eV
1	61	3.295[-21]	2.952[-21]	2.518[-21]	1.948[-21]	1.343[-21]
1	62	3.794[-23]	2.702[-23]	1.661[-23]	7.729[-24]	2.695[-24]
1	63	9.229[-23]	8.080[-23]	6.893[-23]	5.628[-23]	4.452[-23]
1	64	2.916[-23]	2.086[-23]	1.294[-23]	6.216[-24]	2.476[-24]
1	65	1.020[-22]	7.932[-23]	5.680[-23]	3.608[-23]	2.282[-23]
1	66	2.313[-22]	2.244[-22]	2.215[-22]	2.212[-22]	2.153[-22]
1	67	2.801[-24]	2.150[-24]	1.514[-24]	9.360[-25]	5.460[-25]
1	68	1.710[-22]	1.277[-22]	8.324[-23]	4.097[-23]	1.413[-23]
1	69	2.228[-22]	2.269[-22]	2.344[-22]	2.429[-22]	2.397[-22]
1	70	2.826[-22]	2.886[-22]	3.002[-22]	3.157[-22]	3.170[-22]
1	71	5.405[-23]	4.785[-23]	4.187[-23]	3.647[-23]	3.201[-23]
1	72	2.266[-22]	2.398[-22]	2.564[-22]	2.741[-22]	2.754[-22]
1	73	2.013[-22]	2.244[-22]	2.516[-22]	2.803[-22]	2.889[-22]
1	74	4.230[-22]	3.785[-22]	3.229[-22]	2.504[-22]	1.735[-22]
1	75	2.384[-22]	2.489[-22]	2.633[-22]	2.814[-22]	2.854[-22]
1	76	9.947[-23]	9.508[-23]	9.184[-23]	9.054[-23]	8.802[-23]
1	77	1.225[-23]	8.777[-24]	5.431[-24]	2.540[-24]	8.822[-25]
1	78	2.335[-23]	1.970[-23]	1.605[-23]	1.275[-23]	1.045[-23]
1	79	1.642[-23]	1.593[-23]	1.565[-23]	1.571[-23]	1.556[-23]
1	80	2.288[-24]	1.954[-24]	1.594[-24]	1.217[-24]	8.981[-25]
1	81	9.597[-23]	6.948[-23]	4.335[-23]	2.012[-23]	6.556[-24]
1	82	1.901[-22]	1.376[-22]	8.582[-23]	3.980[-23]	1.295[-23]
1	83	4.936[-22]	3.566[-22]	2.218[-22]	1.024[-22]	3.313[-23]
1	84	2.874[-22]	2.084[-22]	1.305[-22]	6.127[-23]	2.068[-23]
1	85	5.400[-22]	4.373[-22]	3.317[-22]	2.276[-22]	1.478[-22]
1	86	7.097[-22]	6.483[-22]	5.750[-22]	4.801[-22]	3.697[-22]
1	87	1.202[-21]	1.125[-21]	1.025[-21]	8.801[-22]	6.911[-22]
1	88	2.955[-23]	2.711[-23]	2.510[-23]	2.362[-23]	2.266[-23]
1	89	4.154[-22]	3.753[-22]	3.286[-22]	2.707[-22]	2.065[-22]
1	90	1.553[-22]	1.365[-22]	1.156[-22]	9.185[-23]	6.818[-23]
1	91	8.909[-24]	7.113[-24]	5.280[-24]	3.543[-24]	2.425[-24]
1	92	7.379[-23]	7.527[-23]	7.820[-23]	8.150[-23]	8.218[-23]
1	93	7.114[-22]	6.715[-22]	6.174[-22]	5.350[-22]	4.232[-22]
1	94	2.716[-23]	2.473[-23]	2.277[-23]	2.136[-23]	2.060[-23]
1	95	7.035[-22]	6.829[-22]	6.463[-22]	5.758[-22]	4.640[-22]
1	96	4.685[-22]	4.591[-22]	4.386[-22]	3.941[-22]	3.194[-22]
1	97	1.068[-21]	1.021[-21]	9.510[-22]	8.347[-22]	6.661[-22]
1	98	5.262[-22]	4.816[-22]	4.282[-22]	3.588[-22]	2.773[-22]
1	99	1.419[-23]	1.100[-23]	7.601[-24]	4.243[-24]	1.965[-24]
1	100	1.693[-22]	1.418[-22]	1.129[-22]	8.307[-23]	5.783[-23]
1	101	8.578[-24]	6.257[-24]	3.960[-24]	1.905[-24]	6.879[-25]
1	102	6.149[-23]	5.480[-23]	4.725[-23]	3.830[-23]	2.893[-23]
1	103	1.605[-22]	1.447[-22]	1.265[-22]	1.041[-22]	7.962[-23]
1	104	2.722[-22]	2.537[-22]	2.305[-22]	1.977[-22]	1.557[-22]
1	105	6.114[-23]	4.660[-23]	3.201[-23]	1.853[-23]	9.744[-24]
1	106	3.181[-23]	2.666[-23]	2.125[-23]	1.566[-23]	1.095[-23]
1	107	1.517[-22]	1.350[-22]	1.162[-22]	9.405[-23]	7.107[-23]
1	108	8.922[-23]	8.018[-23]	6.983[-23]	5.729[-23]	4.372[-23]
1	109	1.250[-24]	1.150[-24]	1.050[-24]	9.477[-25]	8.555[-25]
1	110	2.128[-24]	1.766[-24]	1.382[-24]	9.886[-25]	6.735[-25]
1	111	5.312[-24]	4.379[-24]	3.363[-24]	2.288[-24]	1.421[-24]
1	112	4.755[-24]	3.869[-24]	2.961[-24]	2.080[-24]	1.422[-24]
1	113	1.280[-23]	1.155[-23]	1.021[-23]	8.732[-24]	7.257[-24]
2	3	1.361[-19]	8.104[-20]	5.070[-20]	3.092[-20]	1.816[-20]
2	4	1.086[-23]	7.991[-24]	5.107[-24]	2.449[-24]	8.222[-25]
2	5	7.387[-24]	6.868[-24]	6.471[-24]	6.158[-24]	5.775[-24]
2	6	1.378[-23]	1.095[-23]	8.085[-24]	5.382[-24]	3.578[-24]

TABLE V. Electron Impact Excitation Cross Sections Calculated by the 279-Level MCDF Configuration Expansion

See page 100 for Explanation of Tables

I	F	200 eV	500 eV	1000 eV	2000 eV	4000 eV
2	7	2.259[-22]	1.714[-22]	1.163[-22]	6.510[-23]	3.290[-23]
2	8	2.261[-22]	2.416[-22]	2.598[-22]	2.783[-22]	2.800[-22]
2	9	1.975[-23]	1.483[-23]	9.995[-24]	5.607[-24]	2.795[-24]
2	10	2.219[-23]	1.642[-23]	1.088[-23]	5.987[-24]	2.974[-24]
2	11	3.170[-22]	2.347[-22]	1.510[-22]	7.302[-23]	2.471[-23]
2	12	4.657[-22]	4.981[-22]	5.372[-22]	5.754[-22]	5.776[-22]
2	13	4.782[-23]	4.064[-23]	3.251[-23]	2.325[-23]	1.487[-23]
2	14	2.388[-23]	1.873[-23]	1.364[-23]	8.890[-24]	5.495[-24]
2	15	2.253[-23]	1.592[-23]	9.663[-24]	4.340[-24]	1.367[-24]
2	16	1.997[-23]	1.429[-23]	8.836[-24]	4.129[-24]	1.436[-24]
2	17	7.687[-23]	5.818[-23]	3.974[-23]	2.290[-23]	1.192[-23]
2	18	1.069[-22]	7.736[-23]	4.890[-23]	2.407[-23]	9.460[-24]
2	19	3.569[-22]	2.605[-22]	1.656[-22]	8.065[-23]	2.948[-23]
2	20	6.610[-22]	5.082[-22]	3.556[-22]	2.132[-22]	1.167[-22]
2	21	6.595[-22]	4.752[-22]	2.985[-22]	1.455[-22]	5.642[-23]
2	22	8.447[-22]	7.031[-22]	5.568[-22]	4.070[-22]	2.806[-22]
2	23	4.425[-22]	3.488[-22]	2.524[-22]	1.574[-22]	8.770[-23]
2	24	4.995[-22]	4.034[-22]	3.058[-22]	2.103[-22]	1.370[-22]
2	25	2.944[-22]	2.777[-22]	2.639[-22]	2.526[-22]	2.370[-22]
2	26	8.588[-22]	6.106[-22]	3.733[-22]	1.692[-22]	5.375[-23]
2	27	4.761[-22]	3.554[-22]	2.368[-22]	1.296[-22]	6.229[-23]
2	28	5.734[-23]	4.012[-23]	2.419[-23]	1.108[-23]	3.991[-24]
2	29	8.492[-23]	7.122[-23]	5.756[-23]	4.437[-23]	3.368[-23]
2	30	4.630[-23]	3.146[-23]	1.802[-23]	7.400[-24]	2.109[-24]
2	31	6.039[-22]	4.945[-22]	3.831[-22]	2.729[-22]	1.849[-22]
2	32	2.718[-23]	2.184[-23]	1.660[-23]	1.171[-23]	8.145[-24]
2	33	4.250[-22]	3.280[-22]	2.316[-22]	1.420[-22]	8.103[-23]
2	34	2.910[-23]	1.999[-23]	1.162[-23]	4.861[-24]	1.385[-24]
2	35	1.764[-23]	1.371[-23]	9.940[-24]	6.506[-24]	4.057[-24]
2	36	2.708[-23]	1.934[-23]	1.207[-23]	5.930[-24]	2.479[-24]
2	37	1.770[-22]	1.636[-22]	1.483[-22]	1.299[-22]	1.085[-22]
2	38	6.629[-21]	5.819[-21]	4.841[-21]	3.629[-21]	2.422[-21]
2	39	4.884[-23]	3.337[-23]	1.938[-23]	8.304[-24]	2.727[-24]
2	40	9.371[-23]	6.894[-23]	4.577[-23]	2.629[-23]	1.494[-23]
2	41	1.454[-22]	1.005[-22]	5.902[-23]	2.527[-23]	7.690[-24]
2	42	6.618[-22]	4.710[-22]	2.909[-22]	1.387[-22]	5.366[-23]
2	43	1.233[-21]	9.237[-22]	6.296[-22]	3.743[-22]	2.183[-22]
2	44	9.987[-22]	6.931[-22]	4.100[-22]	1.787[-22]	5.719[-23]
2	45	7.107[-21]	6.224[-21]	5.165[-21]	3.862[-21]	2.574[-21]
2	46	8.935[-22]	7.012[-22]	5.080[-22]	3.251[-22]	1.955[-22]
2	47	9.201[-22]	6.359[-22]	3.728[-22]	1.580[-22]	4.589[-23]
2	48	5.769[-22]	4.686[-22]	3.634[-22]	2.628[-22]	1.807[-22]
2	49	1.717[-21]	1.493[-21]	1.265[-21]	1.029[-21]	8.149[-22]
2	50	9.536[-22]	7.629[-22]	5.766[-22]	4.002[-22]	2.640[-22]
2	51	1.261[-21]	8.724[-22]	5.114[-22]	2.159[-22]	6.210[-23]
2	52	8.173[-22]	5.860[-22]	3.699[-22]	1.884[-22]	8.482[-23]
2	53	1.238[-21]	1.042[-21]	8.460[-22]	6.508[-22]	4.912[-22]
2	54	6.484[-22]	4.848[-22]	3.335[-22]	2.051[-22]	1.232[-22]
2	55	3.184[-21]	2.885[-21]	2.561[-21]	2.180[-21]	1.776[-21]
2	56	6.476[-22]	4.695[-22]	3.031[-22]	1.626[-22]	8.026[-23]
2	57	1.308[-20]	1.264[-20]	1.200[-20]	1.090[-20]	9.268[-21]
2	58	1.057[-20]	1.020[-20]	9.668[-21]	8.757[-21]	7.418[-21]
2	59	5.711[-24]	4.095[-24]	2.526[-24]	1.156[-24]	3.702[-25]
2	60	1.538[-23]	1.119[-23]	7.125[-24]	3.558[-24]	1.435[-24]
2	61	5.499[-23]	3.905[-23]	2.394[-23]	1.113[-23]	3.896[-24]
2	62	9.833[-22]	8.731[-22]	7.371[-22]	5.633[-22]	3.836[-22]
2	63	1.411[-21]	1.039[-21]	6.855[-22]	3.806[-22]	1.951[-22]
2	64	1.256[-20]	1.204[-20]	1.133[-20]	1.025[-20]	8.721[-21]
2	65	5.260[-24]	3.836[-24]	2.449[-24]	1.218[-24]	4.842[-25]

TABLE V. Electron Impact Excitation Cross Sections Calculated by the 279-Level MCDF Configuration Expansion

See page 100 for Explanation of Tables

I	F	200 eV	500 eV	1000 eV	2000 eV	4000 eV
2	66	4.496[-24]	3.452[-24]	2.421[-24]	1.472[-24]	8.294[-25]
2	67	1.833[-21]	1.625[-21]	1.370[-21]	1.047[-21]	7.138[-22]
2	68	4.229[-24]	2.954[-24]	1.752[-24]	7.508[-25]	2.190[-25]
2	69	1.801[-23]	1.474[-23]	1.126[-23]	7.664[-24]	4.813[-24]
2	70	1.720[-24]	1.409[-24]	1.099[-24]	7.965[-25]	5.477[-25]
2	71	4.204[-23]	4.053[-23]	3.918[-23]	3.744[-23]	3.458[-23]
2	72	7.480[-23]	7.013[-23]	6.663[-23]	6.394[-23]	6.090[-23]
2	73	1.051[-23]	7.663[-24]	4.866[-24]	2.365[-24]	8.744[-25]
2	74	1.604[-22]	1.144[-22]	7.043[-23]	3.272[-23]	1.126[-23]
2	75	6.982[-23]	5.207[-23]	3.390[-23]	1.675[-23]	5.907[-24]
2	76	1.078[-22]	1.094[-22]	1.140[-22]	1.199[-22]	1.210[-22]
2	77	3.460[-21]	3.107[-21]	2.659[-21]	2.065[-21]	1.429[-21]
2	78	5.368[-23]	4.098[-23]	2.810[-23]	1.599[-23]	8.191[-24]
2	79	3.310[-22]	3.496[-22]	3.727[-22]	3.934[-22]	3.891[-22]
2	80	3.451[-22]	3.402[-22]	3.406[-22]	3.450[-22]	3.380[-22]
2	81	7.632[-25]	5.585[-25]	3.562[-25]	1.751[-25]	6.647[-26]
2	82	4.624[-24]	3.368[-24]	2.131[-24]	1.030[-24]	3.779[-25]
2	83	8.368[-26]	5.626[-26]	3.209[-26]	1.335[-26]	3.923[-27]
2	84	7.994[-24]	6.002[-24]	4.027[-24]	2.232[-24]	1.096[-24]
2	85	8.546[-24]	6.149[-24]	3.809[-24]	1.752[-24]	5.667[-25]
2	86	2.703[-23]	2.036[-23]	1.374[-23]	7.697[-24]	3.845[-24]
2	87	1.473[-24]	1.080[-24]	6.887[-25]	3.354[-25]	1.223[-25]
2	88	3.600[-22]	3.726[-22]	3.888[-22]	4.078[-22]	4.062[-22]
2	89	5.201[-23]	4.448[-23]	3.642[-23]	2.773[-23]	1.983[-23]
2	90	2.895[-23]	2.107[-23]	1.328[-23]	6.316[-24]	2.185[-24]
2	91	2.229[-22]	2.467[-22]	2.752[-22]	3.079[-22]	3.220[-22]
2	92	1.797[-22]	1.343[-22]	8.757[-23]	4.312[-23]	1.489[-23]
2	93	2.835[-22]	2.457[-22]	2.046[-22]	1.591[-22]	1.158[-22]
2	94	2.619[-22]	2.733[-22]	2.895[-22]	3.110[-22]	3.197[-22]
2	95	8.217[-23]	5.977[-23]	3.769[-23]	1.802[-23]	6.415[-24]
2	96	1.607[-23]	1.169[-23]	7.363[-24]	3.501[-24]	1.217[-24]
2	97	2.061[-22]	1.485[-22]	9.210[-23]	4.235[-23]	1.363[-23]
2	98	4.211[-22]	3.847[-22]	3.411[-22]	2.845[-22]	2.185[-22]
2	99	5.278[-23]	3.996[-23]	2.680[-23]	1.434[-23]	6.419[-24]
2	100	2.154[-22]	1.727[-22]	1.289[-22]	8.640[-23]	5.469[-23]
2	101	1.246[-21]	1.115[-21]	9.661[-22]	7.864[-22]	5.943[-22]
2	102	9.714[-22]	9.077[-22]	8.254[-22]	7.072[-22]	5.545[-22]
2	103	1.143[-21]	1.058[-21]	9.525[-22]	8.082[-22]	6.304[-22]
2	104	5.475[-22]	3.969[-22]	2.480[-22]	1.151[-22]	3.746[-23]
2	105	8.386[-22]	7.874[-22]	7.202[-22]	6.213[-22]	4.906[-22]
2	106	1.416[-22]	1.026[-22]	6.406[-23]	2.975[-23]	9.719[-24]
2	107	1.473[-21]	1.405[-21]	1.307[-21]	1.146[-21]	9.152[-22]
2	108	8.569[-22]	8.022[-22]	7.314[-22]	6.289[-22]	4.955[-22]
2	109	2.670[-24]	2.551[-24]	2.431[-24]	2.317[-24]	2.157[-24]
2	110	6.101[-24]	5.012[-24]	3.813[-24]	2.531[-24]	1.491[-24]
2	111	6.493[-24]	5.345[-24]	4.133[-24]	2.903[-24]	1.939[-24]
2	112	2.146[-23]	2.004[-23]	1.841[-23]	1.642[-23]	1.401[-23]
2	113	8.742[-24]	6.786[-24]	4.810[-24]	2.951[-24]	1.676[-24]
3	4	2.367[-24]	1.863[-24]	1.372[-24]	9.114[-25]	5.703[-25]
3	5	1.781[-24]	1.423[-24]	1.070[-24]	7.286[-25]	4.649[-25]
3	6	6.262[-24]	5.172[-24]	4.016[-24]	2.783[-24]	1.736[-24]
3	7	1.035[-24]	7.218[-25]	4.321[-25]	1.938[-25]	6.608[-26]
3	8	8.340[-25]	6.360[-25]	4.404[-25]	2.587[-25]	1.347[-25]
3	9	2.769[-24]	2.392[-24]	2.037[-24]	1.717[-24]	1.433[-24]
3	10	2.189[-24]	1.572[-24]	9.889[-25]	4.852[-25]	1.884[-25]
3	11	6.493[-24]	5.533[-24]	4.515[-24]	3.403[-24]	2.365[-24]
3	12	4.906[-24]	4.225[-24]	3.490[-24]	2.665[-24]	1.871[-24]

TABLE V. Electron Impact Excitation Cross Sections Calculated
by the 279-Level MCDF Configuration Expansion
See page 100 for Explanation of Tables

I	F	200 eV	500 eV	1000 eV	2000 eV	4000 eV
3	13	1.633[-24]	1.367[-24]	1.115[-24]	8.763[-25]	6.793[-25]
3	14	2.574[-24]	1.861[-24]	1.177[-24]	5.761[-25]	2.171[-25]
3	15	1.411[-24]	9.877[-25]	6.191[-25]	3.305[-25]	1.689[-25]
3	16	5.352[-24]	5.105[-24]	4.832[-24]	4.433[-24]	3.853[-24]
3	17	7.785[-24]	7.483[-24]	7.084[-24]	6.399[-24]	5.412[-24]
3	18	4.961[-24]	4.240[-24]	3.546[-24]	2.859[-24]	2.295[-24]
3	19	1.227[-24]	9.207[-25]	6.234[-25]	3.564[-25]	1.906[-25]
3	20	3.234[-24]	2.969[-24]	2.770[-24]	2.600[-24]	2.400[-24]
3	21	2.532[-24]	1.820[-24]	1.132[-24]	5.264[-25]	1.730[-25]
3	22	2.241[-24]	1.695[-24]	1.189[-24]	7.459[-25]	4.419[-25]
3	23	1.293[-24]	1.103[-24]	9.236[-25]	7.576[-25]	6.171[-25]
3	24	1.089[-24]	7.765[-25]	4.792[-25]	2.220[-25]	7.371[-26]
3	25	8.874[-24]	7.374[-24]	5.769[-24]	4.047[-24]	2.564[-24]
3	26	3.127[-24]	2.329[-24]	1.600[-24]	9.768[-25]	5.660[-25]
3	27	7.614[-24]	8.231[-24]	8.859[-24]	9.330[-24]	9.085[-24]
3	28	4.344[-24]	3.141[-24]	1.996[-24]	1.005[-24]	4.206[-25]
3	29	2.861[-24]	2.076[-24]	1.327[-24]	6.798[-25]	2.984[-25]
3	30	4.661[-24]	3.311[-24]	2.030[-24]	9.304[-25]	3.020[-25]
3	31	1.523[-24]	1.102[-24]	7.072[-25]	3.672[-25]	1.624[-25]
3	32	1.922[-24]	1.457[-24]	9.962[-25]	5.694[-25]	2.849[-25]
3	33	1.827[-23]	1.860[-23]	1.864[-23]	1.808[-23]	1.632[-23]
3	34	1.612[-25]	1.124[-25]	7.171[-26]	4.126[-26]	2.432[-26]
3	35	4.734[-25]	3.346[-25]	2.075[-25]	1.020[-25]	4.212[-26]
3	36	1.783[-23]	1.502[-23]	1.189[-23]	8.380[-24]	5.272[-24]
3	37	2.443[-24]	1.853[-24]	1.292[-24]	8.012[-25]	4.869[-25]
3	38	2.272[-23]	2.364[-23]	2.425[-23]	2.415[-23]	2.222[-23]
3	39	2.068[-24]	1.520[-24]	1.009[-24]	5.757[-25]	3.150[-25]
3	40	1.359[-23]	1.193[-23]	1.008[-23]	7.909[-24]	5.700[-24]
3	41	2.247[-23]	1.970[-23]	1.661[-23]	1.300[-23]	9.349[-24]
3	42	1.745[-24]	1.247[-24]	7.694[-25]	3.542[-25]	1.147[-25]
3	43	2.458[-24]	1.824[-24]	1.208[-24]	6.593[-25]	3.167[-25]
3	44	4.015[-24]	2.854[-24]	1.750[-24]	8.001[-25]	2.584[-25]
3	45	3.178[-24]	2.391[-24]	1.628[-24]	9.388[-25]	5.005[-25]
3	46	1.738[-23]	1.590[-23]	1.432[-23]	1.245[-23]	1.038[-23]
3	47	3.024[-24]	2.533[-24]	2.021[-24]	1.485[-24]	1.022[-24]
3	48	5.131[-24]	4.604[-24]	3.984[-24]	3.205[-24]	2.355[-24]
3	49	1.930[-24]	1.395[-24]	8.833[-25]	4.436[-25]	1.906[-25]
3	50	5.160[-25]	3.666[-25]	2.355[-25]	1.313[-25]	7.144[-26]
3	51	5.135[-25]	3.656[-25]	2.393[-25]	1.416[-25]	8.492[-26]
3	52	3.550[-24]	3.019[-24]	2.464[-24]	1.876[-24]	1.344[-24]
3	53	5.790[-23]	4.901[-23]	3.899[-23]	2.765[-23]	1.749[-23]
3	54	1.168[-24]	8.173[-25]	4.917[-25]	2.204[-25]	7.091[-26]
3	55	2.473[-24]	1.824[-24]	1.194[-24]	6.378[-25]	3.010[-25]
3	56	5.801[-24]	4.776[-24]	3.717[-24]	2.639[-24]	1.749[-24]
3	57	3.142[-24]	2.445[-24]	1.768[-24]	1.147[-24]	7.078[-25]
3	58	1.622[-23]	1.387[-23]	1.118[-23]	8.056[-24]	5.178[-24]
3	59	3.219[-22]	2.373[-22]	1.519[-22]	7.296[-23]	2.452[-23]
3	60	4.188[-22]	4.316[-22]	4.476[-22]	4.633[-22]	4.557[-22]
3	61	2.538[-22]	2.154[-22]	1.776[-22]	1.430[-22]	1.181[-22]
3	62	2.280[-22]	2.392[-22]	2.523[-22]	2.651[-22]	2.631[-22]
3	63	3.964[-23]	3.427[-23]	2.848[-23]	2.203[-23]	1.582[-23]
3	64	3.872[-23]	3.475[-23]	3.008[-23]	2.421[-23]	1.781[-23]
3	65	7.263[-22]	5.274[-22]	3.323[-22]	1.585[-22]	5.502[-23]
3	66	7.847[-22]	6.286[-22]	4.720[-22]	3.211[-22]	2.069[-22]
3	67	2.002[-22]	2.042[-22]	2.109[-22]	2.172[-22]	2.127[-22]
3	68	8.932[-22]	6.336[-22]	3.864[-22]	1.747[-22]	5.544[-23]
3	69	5.430[-22]	4.103[-22]	2.796[-22]	1.605[-22]	8.330[-23]
3	70	6.880[-22]	5.688[-22]	4.467[-22]	3.240[-22]	2.228[-22]
3	71	7.116[-22]	5.965[-22]	4.697[-22]	3.302[-22]	2.086[-22]

TABLE V. Electron Impact Excitation Cross Sections Calculated by the 279-Level MCDF Configuration Expansion

See page 100 for Explanation of Tables

I	F	200 eV	500 eV	1000 eV	2000 eV	4000 eV
3	72	4.133[-22]	3.114[-22]	2.119[-22]	1.224[-22]	6.483[-23]
3	73	1.565[-21]	1.318[-21]	1.042[-21]	7.342[-22]	4.631[-22]
3	74	4.590[-22]	4.619[-22]	4.692[-22]	4.753[-22]	4.581[-22]
3	75	6.021[-22]	4.311[-22]	2.672[-22]	1.259[-22]	4.504[-23]
3	76	5.754[-22]	4.809[-22]	3.822[-22]	2.800[-22]	1.932[-22]
3	77	1.131[-22]	8.696[-23]	6.031[-23]	3.514[-23]	1.881[-23]
3	78	1.733[-21]	1.495[-21]	1.219[-21]	8.932[-22]	5.846[-22]
3	79	3.053[-21]	2.650[-21]	2.175[-21]	1.606[-21]	1.057[-21]
3	80	4.811[-22]	3.827[-22]	2.835[-22]	1.881[-22]	1.180[-22]
3	81	6.994[-22]	4.914[-22]	2.959[-22]	1.317[-22]	4.185[-23]
3	82	1.211[-21]	8.522[-22]	5.154[-22]	2.333[-22]	7.894[-23]
3	83	1.327[-21]	9.132[-22]	5.322[-22]	2.232[-22]	6.378[-23]
3	84	1.149[-21]	7.967[-22]	4.698[-22]	2.014[-22]	5.963[-23]
3	85	9.487[-22]	6.760[-22]	4.236[-22]	2.146[-22]	9.720[-23]
3	86	8.856[-22]	6.332[-22]	3.981[-22]	2.014[-22]	8.966[-23]
3	87	7.981[-22]	6.576[-22]	5.203[-22]	3.857[-22]	2.704[-22]
3	88	4.578[-22]	3.445[-22]	2.332[-22]	1.325[-22]	6.803[-23]
3	89	2.733[-21]	2.510[-21]	2.254[-21]	1.944[-21]	1.594[-21]
3	90	4.898[-21]	4.685[-21]	4.390[-21]	3.935[-21]	3.306[-21]
3	91	6.191[-22]	5.164[-22]	4.035[-22]	2.804[-22]	1.752[-22]
3	92	8.177[-22]	6.793[-22]	5.361[-22]	3.905[-22]	2.690[-22]
3	93	6.111[-22]	4.307[-22]	2.649[-22]	1.295[-22]	5.584[-23]
3	94	3.221[-22]	2.300[-22]	1.409[-22]	6.349[-23]	1.985[-23]
3	95	1.386[-21]	1.152[-21]	9.199[-22]	6.960[-22]	5.191[-22]
3	96	3.242[-21]	2.994[-21]	2.707[-21]	2.340[-21]	1.919[-21]
3	97	8.729[-22]	6.118[-22]	3.710[-22]	1.742[-22]	6.850[-23]
3	98	8.995[-22]	6.989[-22]	5.052[-22]	3.282[-22]	2.025[-22]
3	99	1.165[-20]	1.026[-20]	8.565[-21]	6.450[-21]	4.323[-21]
3	100	8.106[-21]	7.728[-21]	7.234[-21]	6.473[-21]	5.439[-21]
3	101	7.570[-22]	5.721[-22]	3.959[-22]	2.404[-22]	1.385[-22]
3	102	9.295[-21]	8.880[-21]	8.333[-21]	7.480[-21]	6.299[-21]
3	103	6.815[-22]	4.849[-22]	3.002[-22]	1.455[-22]	5.944[-23]
3	104	9.074[-22]	7.087[-22]	5.160[-22]	3.391[-22]	2.125[-22]
3	105	7.775[-21]	7.353[-21]	6.821[-21]	6.096[-21]	5.150[-21]
3	106	8.706[-21]	8.407[-21]	7.958[-21]	7.241[-21]	6.179[-21]
3	107	5.113[-22]	3.501[-22]	2.023[-22]	8.416[-23]	2.479[-23]
3	108	5.367[-21]	5.138[-21]	4.823[-21]	4.352[-21]	3.692[-21]
3	109	2.482[-21]	2.203[-21]	1.861[-21]	1.426[-21]	9.769[-22]
3	110	2.665[-22]	2.586[-22]	2.538[-22]	2.540[-22]	2.488[-22]
3	111	5.259[-22]	5.128[-22]	5.060[-22]	5.093[-22]	5.031[-22]
3	112	1.667[-21]	1.498[-21]	1.305[-21]	1.068[-21]	8.120[-22]
3	113	2.484[-21]	2.234[-21]	1.946[-21]	1.596[-21]	1.214[-21]