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Cross Sections and Rate Coefficients for Excitation of $\Delta n=1$ Transitions in Li-like Ions with $6 < Z < 42$

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Abstract

Excitation cross sections and rate coefficients by electron impact were calculated for the $1s^2 2s - 1s 2s 2p$, $1s^2 2s - 1s 2s^2$ and $1s^2 2s - 1s 2p^2$ transitions of the Li-like ions (CIV, NV, OVI, NeVIII, MgX, AlXI, SiXII, SXIV, ArXVI, CaXVIII, TiXX, FeXXIV, NiXXVI, ZnXXVIII, GeXXX, SeXXXII, KrXXXIIIV and MoXXXXX) in the Coulomb-Born approximation with exchange including relativistic effects and configuration interaction. Level energies, mixing coefficients and transition wavelengths and probabilities were also computed.

Calculations performed by the $1/Z$ perturbation theory and Coulomb-Born approximation are compared with the R-matrix method and the distorted-wave approximation where Z is the nuclear charge.

Formulae obtained for the angular factors of n -electron atomic system allow one to generalize this method to an arbitrary system of highly charged ions.

Keywords: Li-like ions, inner shell excitation, cross section, rate coefficients, $6 < Z < 42$

1. Introduction

The dielectronic satellite lines are important for plasma diagnostics to determine the electron temperature in plasmas from X-ray spectra. The dielectronic satellite for He- and Li-like ions spectra were studied by Gabriel [1], Bhalla et al [2], Bely-Dubau et al [3-5], Vainshtein et al [6], Dubau et al [7], Nilsen [8], Chen [9].

The importance of the electron capture process by an ion followed by stabilization of photon emission (i.e., dielectronic recombination process) in high temperature plasma has become increasingly appreciated since Burgess [10] pointed out that the recombination rate is substantially enhanced by this process. Shore [11], Gau and Hann [12], Bell and Seaton [13] have considered dielectronic recombination from the viewpoint of the quantum theory of resonant collision processes and made clear several distinct approximations which other authors have considered more precisely. The formal reaction theory was employed in [12] to define the contribution of the open channels to the energy shifts and resonance widths; correct expressions were derived for the radiative and Auger branching ratios associated with each stage of the cascade transitions. Formulae derived from *ab initio* theory [13] were compared with those deduced previously [10] using intuitive arguments. Quite little difference in the calculated total dielectronic recombination rates for plasma conditions was found in [13].

The possibility of the direct observation of dielectronic recombination over the inner-shell transitions produced by so called dielectronic satellites in X-ray spectra of θ -pinch was directly pointed out by Gabriel & Jordan [14] and discussed later by Gabriel [1] and Vainshtein et al [15] for solar plasma. Theoretical predictions are presented in [16] for the iron $K\alpha$ X-ray emission spectra from high-temperature astrophysical and laboratory plasmas, assuming optically thin plasma excitation condition. Recently, this process was studied by Wong et al [17] for plasma obtained by EBIT. Theory and analytical results for the scattering amplitude for emission of dielectronic satellites in the framework of the quantum description of resonance scattering in the Coulomb field (based on the approach developed by Presnyakov [18]) were given in the paper [19] by Urnov. Direct electron excitation processes were

studied by Vainshtein et al [20], Bely-Dubau et al [4], Sampson et al [21-24]. Coulomb-Born-exchange data for collision strengths and collision rates for inner-shell excitation from the levels of the $1s^2 2s$ and $1s^2 2p$ configuration for all fine-structure levels of the $1s 2l 2l'$ [23] and $1s 2l 3l'$ [24] configurations in Li-like ions with $Z=8\div 74$ have been calculated. These results include the effects of configuration mixing, parentage mixing and intermediate coupling scheme of the angular and spin momenta. It should be noted that transition energies and mixing coefficients were calculated using the nodeless Slater functions and as a result the data obtained by this method are not quite precise enough. The $1/Z$ perturbation theory and Coulomb-Born-exchange approximation were used in [20] for calculation of the cross sections and rate coefficients for excitation from $1s^2 2s$ and $1s^2 2p$ configurations to all fine-structure levels of $1s 2l 2l'$ configurations in Li-like ions with $Z= 6\div 32$. This method gives more accurate data for transition energies and for the cross sections and rate coefficients as well. It should be noted that the different fitting formulae were used in papers [20] and [21-24], so it is difficult to find out why the results disagree: because of applying different methods or because of the different fitting formulae used.

In the present paper we calculated cross sections and rate coefficients for excitation from the levels of $1s^2 2s$ configuration to all fine-structure levels $1s 2l 2l'$ in Li-like ions with $Z= 6\div 42$. The $1/Z$ perturbation theory and Coulomb-Born-exchange approximation were used as in [20]. In addition to data given in [20] we obtained data by numerical method without using fitting formulae and so our results are more accurate than results in [20]. We also calculated effective cross sections and rate coefficients for excitation from the levels of $1s^2 2s$ configuration to levels $1s^2 2p$ with the total momentum $J=1/2$. These data were obtained as a direct excitation of $1s^2 2s$ to $2s^2 1s$ level and mixing of $2s^2 1s + 2p^2 1s$ ones by configuration interaction and influence of the relativistic effects. Branching ratios for the transitions from these excited states to $1s^2 2p \ ^2P_{1/2}$, $1s^2 2p \ ^2P_{3/2}$, $1s^2 2s \ ^2S_{1/2}$ levels were included in the final data. We hope that it will be possible to calculate data for inner-shell excitation of Be-, B-, C-, N-, O- like ions since we give the general formula for excitation cross sections for the arbitrary n -electron system.

2. General formulae

2.1. Excitation cross sections calculated by ATOM code

The cross sections of excitation for the transitions between two levels QLSJ, Q'L'S'J (Q, Q' and LSJ, L'S'J are configurations and total quantum numbers of atomic system accordingly) in intermediate coupling scheme can be determined by following formula [25-27]

$$\sigma(\text{QLSJ} - \text{Q'L'S'J}) = \sum_{\ell} \sigma'_{\ell}(n_1 j_1, n_1' j_1') A'_{\ell} + \sum_{\ell} \sigma''_{\ell}(n_1 j_1, n_1' j_1') A''_{\ell} \quad (1)$$

where $\sigma'_{\ell}(n_1 j_1, n_1' j_1')$ is the one-electron cross sections with including the direct and interference parts defined as

$$\begin{aligned} \sigma'_{\ell}(n_1 j_1, n_1' j_1') &= A_0 \sum_{\ell_q \ell_k} P_{\ell}(\ell_q \ell_k n_1 j_1; n_1' j_1' k \ell_k) \\ &\left(\frac{2}{2\ell+1} P_{\ell}(\ell_q \ell_k n_1 j_1; n_1' j_1' k \ell_k) - \sum_{\ell'} (-1)^{\ell+\ell'} P_{\ell}(\ell_q \ell_k n_1 j_1; k \ell_k n_1' j_1') \begin{Bmatrix} j_1 & j_1 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \right) \end{aligned} \quad (2)$$

and $\sigma''_{\ell}(n_1 j_1, n_1' j_1')$ represents the exchange part:

$$\sigma''_{\ell}(n_1 j_1, n_1' j_1') = 2A_0(2\ell+1) \sum_{\ell_q \ell_k} \left[\sum_{\ell'} (-1)^{\ell+\ell'} P_{\ell}(\ell_q \ell_k n_1 j_1; k \ell_k n_1' j_1') \begin{Bmatrix} j_1 & j_1 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \right]^2 \quad (3)$$

where $A_0 = 8\pi a_0^2 / q^2 (2j_1 + 1)$, l is the multiplicity of the direct and interference parts, j_1 , j_1' and l_q , l_k are orbital quantum numbers of bound and free electrons accordingly.

The angular factors are given in [26] for two-electron system outside the closed core. These factors are derived in Appendix A in the general form for an n-electron system and are discussed in the next Section. Following [25] the radial integrals can be presented in the following form:

$$\begin{aligned} P_{\ell}(\ell_q \ell_k n_1 j_1; n_1' j_1' k \ell_k) &= \sqrt{(2\ell_q + 1)(2j_1 + 1)(2\ell_k + 1)(2j_1' + 1)} \begin{pmatrix} \ell & \ell_q & \ell_k \\ 0 & 0 & 0 \end{pmatrix} \\ &\times \begin{pmatrix} \ell & j_1 & j_1' \\ 0 & 0 & 0 \end{pmatrix} \int_0^{\infty} dr_1 \int_0^{\infty} dr_2 \left[\frac{r_1^{\ell}}{r_1^{\ell+1}} - \frac{\delta(\ell, 0)}{r_1} \right] F_{\ell_q \ell_k}(r_1) P_{n_1 j_1}(r_2) F_{k \ell_k}(r_1) P_{n_1' j_1'}(r_2) \end{aligned} \quad (4)$$

$$\begin{aligned}
P_\ell(q\ell_q n_1 j_1; k\ell_k n'_1 j'_1) &= \sqrt{(2\ell_q + 1)(2j_1 + 1)(2\ell_k + 1)(2j'_1 + 1)} \begin{pmatrix} \ell & \ell_q & j_1 \\ 0 & 0 & 0 \end{pmatrix} \\
&\times \begin{pmatrix} \ell & j_1 & \ell_k \\ 0 & 0 & 0 \end{pmatrix} \int_0^\infty dr_1 \int_0^\infty dr_2 \left[\frac{r_1^\ell}{r_1^{\ell+1}} \right] F_{q\ell_q}(r_1) P_{n_1 j_1}(r_2) F_{k\ell_k}(r_2) P_{n'_1 j'_1}(r_1)
\end{aligned} \tag{5}$$

The atomic radial function $P_{nj}(r)$ is a solution of the radial equation in the effective central field of the core for a given energy which is taken from the MZ code (1/Z perturbation theory method). The external electron is described by the Coulomb wave function $F_{\ell q}(r)$ in the field $(Z-N)/r$, where N is the total number of electrons. To find the exchange amplitude, the orthogonalized functions are used [25]:

$$G_{\varepsilon j} = F_{\varepsilon j} - \langle F_{\varepsilon j} | P_{n' j'} \rangle P_{n' j'}, \quad G_{\varepsilon' j'} = F_{\varepsilon' j'} - \langle F_{\varepsilon' j'} | P_{n j} \rangle P_{n j} \tag{6}$$

The calculation of these functions, radial integrals and one-electron cross sections (eqs.(2) - (6)) is carried out using the ATOM code [28].

2.2. Energy levels and mixing coefficients calculated by MZ code

The MZ code [6, 29] is based on the perturbation theory method. The energy matrix in this method (called 1/Z method or Z-expansion one) is represented as an Z-expansion series where Z is the nuclear charge. Because of the use of Coulomb wavefunctions the expansion coefficients are the same for all terms of a given isoelectronic sequence, that is an important advantage of the method. The interaction of terms and configurations inside one complex is already taken into account in the first order coefficients. A complex is a group of configurations with the same parity and the same principal quantum numbers. The interaction of configurations from different complexes is considered in the next orders of the perturbation theory. The relativistic corrections are calculated in the framework of the Breit operators. The radiative and higher order relativistic corrections are taken into account additionally (see for detail [6] and [29]). The energy matrix element can be represented in this form :

$$\begin{aligned}
E(QLSJ, Q'L'S'J) = & \delta(L, L')\delta(S, S') [\delta(Q, Q') E_0^N Z^2 + E_1^N Z + E_2^N + E_3^N / Z^3 \\
& + \frac{\alpha^2}{4} (Z - \sigma^R)^3 (\delta(Q, Q') E_0^R Z + R')] \\
& + \frac{\alpha^2}{4} (Z - \sigma^S)^3 (\delta(Q, Q') E_{S0}^{(0)} Z B_1 + E_{S0}' B_1 + E_{SA}^{(0)} B_1 + E_{SS}^{(0)} B_2)
\end{aligned} \tag{7}$$

Here "Q" designates configuration, LSJ are orbital, spin and total momenta of the system respectively, Z is the nuclear charge, α is the fine structure constant which equal to 1/137.0359 in a.u.. The total moment J is presented only in the factors B_k which are equal to

$$B_k = (-1)^{J+L'+S} \begin{Bmatrix} L' & S' & J \\ L & S & k \end{Bmatrix} \tag{8}$$

where $k=1,2$. Calculation of each coefficient in (1) is carried out by means of the Feynman diagram technique [29]. The coefficients E_i^N determine the nonrelativistic part of energy, three coefficients E_0^R , σ^R and R' give relativistic shift of the term defined by the Breit Hamiltonian and include the contact term, orbit-orbit interaction and the dependence of mass on velocity. Finally, the coefficients $E_{SO}^{(0)}$, σ^S , E_{SO}' , $E_{SA}^{(0)}$ and $E_{SS}^{(0)}$ determine the fine structure splitting of terms which consist of three operators: spin-orbit ($E_{SO}^{(0)}$, σ^S , E_{SO}'), spin-another-orbit ($E_{SA}^{(0)}$) and spin-spin ($E_{SS}^{(0)}$) interactions.

After the diagonalization of the energy matrix, we obtain the energy eigenvalues ($E(Q_L L_J S_J)$) and eigenvectors ($C^J(Q_L S, Q_L L_J S_J)$) for the configurations $1s2s2p$, $1s2p^2$, $1s2s^2$. Table 1 lists the energies of 7 levels of the $1s2s2p$ configuration, 8 levels of $1s2p^2$ configuration and one level of $1s2s^2$ configuration for Li-like ions with $Z=6\div 42$. The energy data of autoionizing states given in this table are counted from the ground state $1s^2 2s^2 S_{1/2}$. Let us explain designations for levels used in Table 1 since they will be used below. The configuration together with intermediate quantum numbers of two electron system is described by letters :

$$C=2s2p(^1P)1s, K=2s2p(^3P)1s, E=2s^2(^1S)1s, M=2p^2(^3P)1s, F=2p^2(^1S)1s, \\ F=2p^2(^1D)1s, S=1s^22s, P=1s^22p \quad (9)$$

and the numbers after letter means $(2S+1)(2L+1)(2J+1)$.

The data given in Table 1 were used for ATOM code as an one-electron excitation energies. For example: the $1s^22s - 1s2s2p$ excitation is described by $1s$ and $2p$ one-electron energies. These energies are obtained as the difference of $1s^22s - 1s2s$ and $1s2s2p - 1s2s$ energies respectively. There are two levels of $1s2s$ configuration and we can use any one. The $1s2s \ ^3S_1$ level was chosen. Table 1c lists $1s$ energies ($E(1s^22s \ ^2S_{1/2}) - E(1s2s \ ^3S_1)$). Table 1d lists $2p$ energies ($E(2s2p \ [^1,^3P]1s \ ^{2,4}P_J) - E(1s2s \ ^3S_1)$) and $2s$ energies ($(E(2s^21s \ ^2S_{1/2}) - E(1s2s \ ^3S_1))$). These energy level data were used in the ATOM code for calculation of $P_{nj}(\mathbf{r})$ functions (see eqs.(4- (6))

2.3 Contribution of relativistic effects to the excitation cross sections of three-electron system

The angular parts (A'_ℓ and A''_ℓ factors in eq.(1)) are studied in detail for n -electron (Appendix A) and 3-electron (Appendix B) systems and we discuss below the contribution of the relativistic effects to these factors and of these factors to the excitation cross sections.

Two special cases of excitation are considered in our here: $j_1^0 j_1^0 [L_{12} S_{12}] j_2^0 L S J - j_3^0 j_2^0 [L'_{12} S'_{12}] j_1^0 L' S' J'$ and $j_1^0 j_1^0 [L_{12} S_{12}] j_2^0 L S J - j_2^0 j_2^0 [L'_{12} S'_{12}] j_1^0 L' S' J'$ which can be joined into one $j_1 j_1 [L_{12} S_{12}] j_2 L S - j_3 j_2 [L'_{12} S'_{12}] j_1 L' S' J'$. The cross sections for this excitation transitions can be represented as (see eq.(B.1)):

$$\begin{aligned} \sigma(j_1 j_1 [L_{12} S_{12}] j_2 L_J S_J J - j_3 j_2 [L'_{12} S'_{12}] j_1 L'_J S'_J J') = \\ = \sum_{\ell} \sigma'_{\ell}(n_1 j_1, n_3 j_3) A'_{\ell}(j_1 j_1 [L_{12} S_{12}] j_2 L_J S_J J - j_3 j_2 [L'_{12} S'_{12}] j_1 L'_J S'_J J') \\ + \sum_{\ell} \sigma''_{\ell}(n_1 j_1, n_3 j_3) A''_{\ell}(j_1 j_1 [L_{12} S_{12}] j_2 L_J S_J J - j_3 j_2 [L'_{12} S'_{12}] j_1 L'_J S'_J J') \end{aligned} \quad (10)$$

where $\sigma'_{\ell}(n_1 j_1, n_3 j_3)$ is the one-electron cross sections with including the direct and interference parts defined by eq.(2) and $\sigma''_{\ell}(j_1, j_3)$ represents the exchange part (see eq.(3)).

For three-electron system the angular factors are equal to

$$\begin{aligned}
A'_\ell(j_1j_1[L_{12}S_{12}]j_2L_J S_J J, j_3j_2[L'_{12}S'_{12}]j_1L'_J S'_J J') &= \frac{1}{(2J+1)} \\
&\times \left[\sum_{QLS} \sum_{Q_J L_J S_J} C^J(QLS, Q_J L_J S_J) C^{J'}(Q' L' S', Q'_J L'_J S'_J) \right. \\
&\times \frac{1}{2} \sum_{L''_{12} S''_{12}} \sum_{\ell_1 \ell_2} C_{\ell_1 j_1 \ell_2 j_2 j_3 j_2} (L_{12} S_{12}, L''_{12} S''_{12}; LS) \\
&\times C_{\ell_1 j_3 \ell_2 j_2 \ell_3 j_1} (L'_{12} S'_{12}, L''_{12} S''_{12}; L' S') f_\ell(\ell_3 \ell'_3; LSJ, L' S' J'; L''_{12}) \left. \right]^2
\end{aligned} \tag{11}$$

$$\begin{aligned}
A''_\ell(j_1j_1[L_{12}S_{12}]j_2L_J S_J J, j_3j_2[L'_{12}S'_{12}]j_1L'_J S'_J J') &= \frac{1}{2(2J+1)(2\ell+1)} \\
&\sum_{a_1} \sum_{a_2} \left[\sum_{QLS} \sum_{Q_J L_J S_J} C^J(QLS, Q_J L_J S_J) C^{J'}(Q' L' S', Q'_J L'_J S'_J) \right. \\
&\times \frac{1}{2} \sum_{L''_{12} S''_{12}} \sum_{\ell_1 \ell_2} C_{\ell_1 j_1 \ell_2 j_2 j_3 j_2} (L_{12} S_{12}, L''_{12} S''_{12}; LS) \\
&\times C_{\ell_1 j_3 \ell_2 j_2 \ell_3 j_1} (L'_{12} S'_{12}, L''_{12} S''_{12}; L' S') f_\ell^{a_1 a_2}(\ell_3 \ell'_3; LSJ, L' S' J'; L''_{12} S''_{12}) \left. \right]^2
\end{aligned} \tag{12}$$

where factors $f_\ell(\ell_3 \ell'_3; LSJ, L' S' J'; L''_{12} S''_{12})$, $f_\ell^{a_1 a_2}(\ell_3 \ell'_3; LSJ, L' S' J'; L''_{12} S''_{12})$ and $C_{\ell_1 j_3 \ell_2 j_2 \ell_3 j_1} (L'_{12} S'_{12}, L''_{12} S''_{12}; L' S')$ are determined by formulae in Appendix A (eqs.(A.30), (A.22) and Appendix B (B.4)).

Let us discuss the influence of relativistic effects on these angular factors A' and A'' . The contribution is defined by intermediate coupling coefficients $C^J(QLS, Q_J L_J S_J)$. Without these coefficients the angular factors can be described as

$$\begin{aligned}
N'_\ell(j_1j_1[L_{12}S_{12}]j_2LSJ, j_3j_2[L'_{12}S'_{12}]j_1L'SJ') &= \frac{1}{(2J+1)} \\
&\times \left[\frac{1}{2} \sum_{L''_{12} S''_{12}} \sum_{\ell_1 \ell_2} C_{\ell_1 j_1 \ell_2 j_2 j_3 j_2} (L_{12} S_{12}, L''_{12} S''_{12}; LS) C_{\ell_1 j_3 \ell_2 j_2 \ell_3 j_1} (L'_{12} S'_{12}, L''_{12} S''_{12}; L' S') \right. \\
&\times f_\ell(\ell_3 \ell'_3; LSJ, L' S' J'; L''_{12}) \left. \right]^2
\end{aligned} \tag{13}$$

$$N_{\ell}''(j_1 j_1 [L_{12} S_{12}] j_2 L S J, j_3 j_2 [L'_{12} S'_{12}] j_1 L' S' J') = \frac{1}{2(2J+1)(2\ell+1)} \sum_{a_1} \sum_{a_2} \left[\frac{1}{2} \sum_{L''_{12} S''_{12}} \sum_{\ell_1 \ell_2} C_{\ell_1 j_1 \ell_2 j_1 \ell_3 j_2} (L_{12} S_{12}, L''_{12} S''_{12}; LS) \times C_{\ell_1 j_3 \ell_2 j_2 \ell_3 j_1} (L'_{12} S'_{12}, L''_{12} S''_{12}; L' S') f_{\ell}^{a_1 a_2} (\ell_3 \ell_3'; LSJ, L' S' J'; L''_{12} S''_{12}) \right]^2 \quad (14)$$

In the case of $j_1 = 0$ all our expressions can be represented in more simple form:

$$N_{\ell}(1s^2 [^1S] j_2 L S J, j_3 j_2 [L'_{12} S'_{12}] l s L' S' J') = \frac{(2S'_{12} + 1)(2L' + 1)(2J' + 1)}{2(2j_3 + 1)} \left\{ \begin{matrix} J & J' & j_3 \\ L' & L & S \end{matrix} \right\}^2 \delta(j_2, L) \delta(j_3, \ell) \delta(L'_{12}, L') \delta(S, S') \quad (15)$$

$$N_{\ell}''(1s^2 [^1S] j_2 L S J, j_3 j_2 [L'_{12} S'_{12}] l s L' S' J') = \delta(j_2, L) \delta(j_3, \ell) \delta(L'_{12}, L') \times ((2S'_{12} + 1)(2L' + 1)(2S + 1)(2S' + 1)(2J' + 1) / 2(2\ell + 1)) \sum_{a_1} \sum_{a_2} (2a_1 + 1)(2a_2 + 1) \times \left\{ \begin{matrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{matrix} \right\}^2 \left\{ \begin{matrix} J & j_3 & a_1 \\ L' & S & L \end{matrix} \right\}^2 \left\{ \begin{matrix} a_1 & J' & a_2 \\ S' & S & L' \end{matrix} \right\}^2 \quad (16)$$

Let us consider $1s^2 [^1S] 2s^2 S_{1/2} - 2p2s [^1P] 1s^2 P_J$ excitation. For this special case we obtain from eqs.(15) and (16):

$$N_{\ell}(1s^2 [^1S] 2s^2 S_{1/2}, 2p2s [^1S'_{12}] l s 1S' J') = \frac{(2S'_{12} + 1)(2J' + 1)}{12} \delta(\ell, 1) \delta(S', \frac{1}{2}) \quad (17)$$

$$N_{\ell}''(1s^2 [^1S] 2s^2 S_{1/2}, 2p2s [^1S'_{12}] l s 1S' J') = \delta(\ell, 1) \frac{(2S'_{12} + 1)(2S' + 1)(2J' + 1)}{4(2\ell + 1)} \times \sum_{a_1} \sum_{a_2} (2a_1 + 1)(2a_2 + 1) \left\{ \begin{matrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{matrix} \right\}^2 \left\{ \begin{matrix} a_1 & J' & a_2 \\ S' & 1/2 & 1 \end{matrix} \right\}^2 \quad (18)$$

Sum over a_1 and a_2 can be calculated by using the formula (B.21). As a result we obtain

$$N_{\ell}''(1s^2 [^1S] 2s^2 S_{1/2}, 2p2s [^1S'_{12}] l s 1S' J') = \delta(\ell, 1) \frac{(2J' + 1)}{12} \quad (19)$$

To obtain formulae for the next particular case $j_3 = j_2$ we should change j_3 to j_2 in eqs.(10) - (14) and multiply eqs. (15) and (16) by factor 2:

$$N_\ell(1s^2[{}^1S]j_2 \text{ LSJ}, j_2 j_2 [L'_{12} S'_{12}] | s L' S' J') = \frac{(2S'_{12} + 1)(2L' + 1)(2J' + 1)}{(2j_2 + 1)} \left\{ \begin{matrix} J & J' & j_2 \\ L' & L & S \end{matrix} \right\}^2 \delta(j_2, L) \delta(j_2, \ell) \delta(L'_{12}, L') \delta(S, S') \quad (20)$$

$$N_\ell^*(1s^2[{}^1S]j_2 \text{ LSJ}, j_2 j_2 [L'_{12} S'_{12}] | s L' S' J') = \delta(j_2, L) \delta(j_2, \ell) \delta(L'_{12}, L') \times ((2S'_{12} + 1)(2L' + 1)(2S + 1)(2S' + 1)(2J' + 1) / (2\ell + 1)) \sum_{a_1} \sum_{a_2} (2a_1 + 1)(2a_2 + 1) \times \left\{ \begin{matrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{matrix} \right\}^2 \left\{ \begin{matrix} J & j_2 & a_1 \\ L' & S & L \end{matrix} \right\}^2 \left\{ \begin{matrix} a_1 & J' & a_2 \\ S' & S & L' \end{matrix} \right\}^2 \quad (21)$$

These formulae are simplified very much in the case $j_2 = 0$:

$$N'_\ell(1s^2[{}^1S]2s \text{ } ^2S_{1/2}, 2s^2[{}^1S] | s \text{ } ^2S_{1/2}) = \delta(\ell, 0) \quad (22)$$

$$N_\ell^*(1s^2[{}^1S]2s \text{ } ^2S_{1/2}, 2s^2[{}^1S] | s \text{ } ^2S_{1/2}) = \delta(\ell, 0) \frac{1}{4} \sum_{a_1} \sum_{a_2=0,1} (2a_2 + 1) \delta(a_1, \frac{1}{2}) = \delta(\ell, 0) \quad (23)$$

Formulae for $j_2 = 1$ are not so simple as for $j_2 = 0$:

$$N_\ell(1s^2[{}^1S]2p \text{ } ^2P_J, 2p^2[L'_{12} S'_{12}] | s L' S' J') = \frac{(2S'_{12} + 1)(2L' + 1)(2J' + 1)}{3} \left\{ \begin{matrix} J & J' & 1 \\ L' & 1 & 1/2 \end{matrix} \right\}^2 \delta(\ell, 1) \delta(L'_{12}, L') \delta(S', \frac{1}{2}) \quad (24)$$

$$N_\ell^*(1s^2[{}^1S]2p \text{ } ^2P_J, 2p^2[L'_{12} S'_{12}] | s L' S' J') = \delta(\ell, 1) \delta(L'_{12}, L') \times \frac{1}{3} (2S'_{12} + 1)(2L' + 1)(2S' + 1)(2J' + 1) \sum_{a_1} \sum_{a_2} (2a_1 + 1)(2a_2 + 1) \times \left\{ \begin{matrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{matrix} \right\}^2 \left\{ \begin{matrix} J & 1 & a_1 \\ L' & 1/2 & 1 \end{matrix} \right\}^2 \left\{ \begin{matrix} a_1 & J' & a_2 \\ S' & 1/2 & L' \end{matrix} \right\}^2 \quad (25)$$

There is no possibility to simplify the expression in eq.(25).

The numerical results for all possible L', S', J and J' quantum numbers are given in Table 2. These results are compared with the data obtained by including intermediate coefficients $C^J(QLS, Q_J L_J S_J)$ (see Table 3). The influence of relativistic effects depends on Z . In the Table 2 these data are given for $Z=26$. We can see from Table 2 that for some transitions (S212-C234, (P232-F212, P232-M234) this influence is very large since N' and N'' decrease more than in 10 times in comparison with A' and A'' . This changing is more drastically for S212-C234 transitions since N' decreases 150 times in comparison with A' but $N''=A''$. It should be noted that $N''=A''$ for all type of $1s^2[{}^1S]2s^2S_{1/2} - 2p2s[{}^{1,3}P]1s^2{}^4P_J$ transitions since N'' is independent of all quantum numbers except J' . In this case

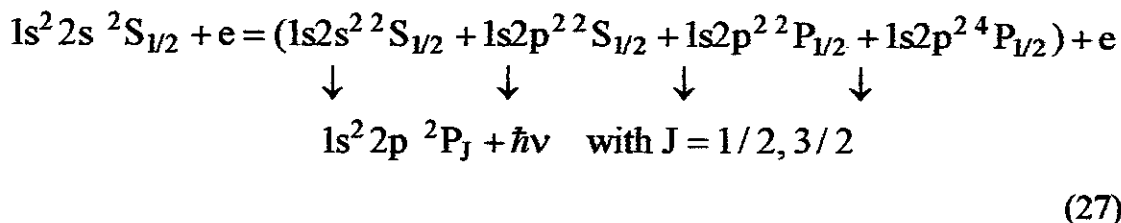
$$\left[\sum_{QLS} C^J(QLS, Q_J L_J S_J) \right]^2 = 1 \quad (26)$$

and we obtained that $A''=N''$ for these type of excitation from comparison of eqs.(11) and (13). Let us underline that $A'=A''$ for 1s-2s excitation (see Table 2) because there is only one kind of allowed excitation in LS coupling scheme- $1s^2[{}^1S]2s^2S_{1/2} - 2s^2[{}^1S]1s^2S_{1/2}$ excitation. The excitation of three other levels ($2p^2[{}^1S]1s^2S_{1/2}$, $2p^2[{}^1S]1s^2P_{1/2}$, $2p^2[{}^1S]1s^4P_{1/2}$) takes place by both superposition of $2s^2[{}^1S]1s^2S_{1/2} + 2p^2[{}^1S]1s^2S_{1/2}$ configurations and influence of relativistic effects together (for $2p^2[{}^1S]1s^4P_{1/2}$ level). The angular coefficients A' and A'' are determined by $(C^J(QLS, Q_J L_J S_J))^2$ factor in eqs.(10) and (11) where $J=1/2$, $QLS=2s^2[{}^1S]1s^2S_{1/2}$ and $Q_J L_J S_J = 2s^2[{}^1S]1s^2S_{1/2}, 2p^2[{}^1S]1s^2S_{1/2}, 2p^2[{}^1S]1s^2P_{1/2}, 2p^2[{}^1S]1s^4P_{1/2}$. Namely these four mixing coefficients determine the angular factors A' and A'' in Table 2.

3. Results and discussion

Results of our calculation are given in Table 3-7 and Figs.1-4. Table 3 lists wavelengths (WL) and angular coefficients A', A'' for 1s-2p (Table 3a) and 1s-2s (Table 3b) excitation for Li-like ions with the nuclear charge $Z=6, 7, 8, 10, 12, 13, 14, 16, 20, 22, 26, 28, 30, 32, 34, 36, 42$. Designations (9) were used for the names of transitions.

Let us consider the angular coefficients A' and A'' for emission lines given in Table 3b. Schematically the excitation process can be represented in the form:



These coefficients were calculated by multiplying A', A'' factors (see 4 last lines for each ion in Table 3b) by branching ratio (K) given in Table 3b for 8 emission lines: $(1s^2 s^2 S_{1/2} - 1s^2 2p^2 P_J)$, $(1s^2 p^2 S_{1/2} - 1s^2 2p^2 P_J)$, $(1s^2 p^2 P_{1/2} - 1s^2 2p^2 P_J)$, $(1s^2 p^2 P_{3/2} - 1s^2 2p^2 P_J)$ with $J=1/2$ and $3/2$). It should be noted that only two lines $(1s^2 p^2 S_{1/2} - 1s^2 2p^2 P_J)$, $(1s^2 p^2 P_{1/2} - 1s^2 2p^2 P_J)$ are allowed in LS coupling scheme, the $1s^2 s^2 S_{1/2} - 1s^2 2p^2 P_J$ line is allowed by superposition of configurations $(1s^2 s^2 + 1s^2 p^2)$ and data for the $1s^2 p^2 P_{1/2} - 1s^2 2p^2 P_J$ line is non zero because of influence of relativistic effects ($\Delta S=1$).

Table 3b lists additional data for emission lines (Q'L'S'J' - QLSJ): radiative transition probabilities (Ar) and autoionizing rate (Γ) which are necessary in order to calculate the branching ratio (K):

$$K(Q'L'S'J'-QLSJ) = \frac{Ar(Q'L'S'J'-QLSJ)}{Ar(Q'L'S'J') + \Gamma(Q'L'S'J')},$$

(28)

$$Ar(Q'L'S'J') = \sum_{QLSJ} Ar(Q'L'S'J'-QLSJ)$$

Except Ar, Γ and K Table 3b gives data for relative factor intensities for dielectronic satellite lines (Qd) which are defined as $Qd = \Gamma K$ for each line. All these data were obtained by MZ program (see part 2.2 and Ref.[7,29]). It should be noted that Table 3a includes also data for Ar, Γ , K and Qd.

Our scaled calculated cross sections (σ_c) for the six $2s2p(^1,^3P)1s^2 P_J - 1s^2 2s^2 S_{1/2}$ transitions for the 17 Li-like ions are given in Table 4 as a function of scaled scattered electron energy u , given in units of $Z_S^2(Ry)$, where $Z_S = Z-2$ is the effective nuclear charge.

$$\sigma = \sigma_{cx} \frac{a_0^2}{Z^4} (\text{cm}^2), E = 13.6 Z^2 (\Delta\varepsilon + u) (\text{eV}) \quad (29)$$

The scaling of both the cross sections and the scattered energy is useful for graph representation (see Figs.1(q)-1(v)) since it was possible to show 14 transitions on one Graph. Let us explain ones more the designations for transitions which are different from shown in eq.(9):

$$\begin{aligned} q &= 2s2p(^3P)1s^2P_{3/2} - 1s^22s^2S_{1/2}, r = 2s2p(^3P)1s^2P_{1/2} - 1s^22s^2S_{1/2}, \\ s &= 2s2p(^1P)1s^2P_{3/2} - 1s^22s^2S_{1/2}, t = 2s2p(^1P)1s^2P_{1/2} - 1s^22s^2S_{1/2}, \\ u &= 2s2p(^3P)1s^4P_{3/2} - 1s^22s^2S_{1/2}, v = 2s2p(^3P)1s^4P_{1/2} - 1s^22s^2S_{1/2} \end{aligned} \quad (30)$$

These designations were introduced by Gabriel et al [1] and widely used. The designations given by eq.(9) were introduced by Vainshtein and Safronova [6] and also used in many papers.

We can see from Figs.1(q) -1(u) that cross sections change smoothly with u and their values does not change very much with Z . For such transitions the curves for different ions (especially for small Z) do not cross in the entire energy interval; the scaled cross sections at the same energy value (u) increases with Z . It should be noted that there are some curves crossing for high Z that can be explained by relativistic effects. We can see from Table 3a that factors A' and A'' change different with Z : A' decreases (r, s), increases (t, u, v) or smoothly changes (q) with maximum for $Z=22$ but A'' is constant for 6 lines and any Z (see part 2.3 and Table 2). It should be noted also that $A' > A''$ for three lines (q, r, t) on all interval of Z and vice versa we have ($A' < A''$) for another three lined (s, u, v). We can see that there are two types of curves: (1) when cross sections increase smoothly with energy u and decrease after maximum for $u = 0.64 - 2.56$ and (2) when σ decreases sharply with u . The first case takes place for q, r, t transitions and the second one is for s, u, v transitions. This behavior of curve can be explained by the predominant contribution of direct cross sections ($A'\sigma'$) for the first case and the exchanging part ($A''\sigma''$) for the second one. This conclusion can

be made because of the fact that the ratio σ''/σ' decreases with energy as E^2 and the sharp decreasing cross sections for the first case (s,u, v transitions) shows that the cross sections for the transitions lines are determined by the exchanging part A'' σ'' .

We have the largest value of A' for q transition and we see from Figs.1 that the values of cross sections for this transition are large than for another 5 transitions for all Z. By relativistic effects A' decreases with Z after maximum for Z=22 and the cross sections for Z>22 increases only a little with Z and begins to decrease for Z=36. The curve of cross sections for Z=42 is placed between curves for Z=22 and Z=26 for the small energy and between curves for Z=16 and 20 for the large energy u crossing the curves for Z=22 and Z=20 around $u=0.32 \div 0.64$. There is more sharp changing of curve for the r transition since A' for this transition decreases with Z from A'=0.606 for Z=6 to 0.231 for Z=42. Because of this decreasing of A' the curve for cross sections with Z=42 is placed between curves for Z=14 and 16 for small energy and between Z=6 and 8 for the large energy while crossing the curves Z=14, 13, 12, 10, 8 around $u=0.04 \div 1.28$.

Table 5 represents cross sections of 1s-2s excitation (σ_C) for 8 emission lines $1s^2 2p - 1s 2s^2$, $1s^2 2p - 1s 2p^2$ for the 17 Li-like ions. The Gabriel's designations [1] were used for these lines also:

$$\begin{aligned}
 o &= 2s^2 1s \ ^2S_{1/2} - 1s^2 2p \ ^2P_{3/2}, & p &= 2s^2 1s \ ^2S_{1/2} - 1s^2 2p \ ^2P_{1/2}, & m &= 2p^2 1s \ ^2S_{1/2} - 1s^2 2p \ ^2P_{3/2}, \\
 n &= 2p^2 1s \ ^2S_{1/2} - 1s^2 2p \ ^2P_{1/2}, & c &= 2p^2 1s \ ^2P_{1/2} - 1s^2 2p \ ^2P_{3/2}, & d &= 2p^2 1s \ ^2P_{1/2} - 1s^2 2p \ ^2P_{1/2}, \\
 h &= 2p^2 1s \ ^4P_{1/2} - 1s^2 2p \ ^2P_{3/2}, & i &= 2p^2 1s \ ^4P_{1/2} - 1s^2 2p \ ^2P_{1/2}
 \end{aligned} \tag{31}$$

The values of these cross sections are much less than for 6 above mentioned transitions since there is only one level ($2s^2 1s \ ^2S_{1/2}$) which can be directly excited from the ground $1s^2 2s \ ^2S_{1/2}$ level (1s - 2s excitation) but there is no allowed dipole transition from this level. There are transitions allowed in LS coupling scheme from the two levels ($2p^2 1s \ ^2S_{1/2}$ and $2p^2 1s \ ^2P_{1/2}$) which are in the same complex as $2s^2 1s \ ^2S_{1/2}$ level but those two levels can not be excited directly but only by superposition of

$2s^21s+ 2p^21s$ configurations and relativistic interaction ($\Delta S=1$). As a result the values of cross sections given by Table 5 are in $10^2 - 10^5$ times less than the values of cross sections given by Table 4. Their ratio of cross sections is proportional Z^n where $n=2\div 6$ since the first order functions obtained by superposition of configurations or relativistic interactions are proportional to Z or Z^3 (see Ref.[30]). Because of this strong dependence on Z we used logarithmic scale for the σ_C for 8 emission lines $1s^22p - 1s2s^2$, $1s^22p - 1s2p^2$ shown on Figs.2o - 2i. We can see from Figs. 2o - 2i that cross sections change smoothly with u and there is no crossing of curves which belongs to cross sections with different Z : $\sigma_C(Z=42)/\sigma_C(Z=6)=10^3 \div 10^5$. Some sharp changing of curves for cross sections with small Z can be explained by the limit of our method since their values are very small (10^{-8}).

The collisional excitation rates, R , were calculated from excitation cross sections assuming a Maxwellian distribution of electron velocities. In Table 7, 8 and Graphs 3, 4 scaled excitation rate coefficients, R_C , are shown as a function of the scaled electron temperature $1/\beta$ in units of Z_S^2 (Ry) for the same 17 Li-like ions. R is obtained from the plotted R_C values by using the next formula:

$$R = 10^{-8} \frac{R_C}{Z_S^3} \exp(-\beta\Delta\varepsilon) \text{ in cm}^3/\text{s}, \quad (32)$$

where $\Delta\varepsilon$ is the transition energy in units of Z_S^2 (Ry) given in Table 6 and 7 as a last line. The variations with energy and Z are very similar to those seen in Graphs 1 and 2 except Fig 1q, 1r and 1t since there are no maximum on curves of the collisional excitation rates.

Comparison of our calculated data with another theoretical calculations and experimental data are given in Table 8 and 9. Table 8 list the excitation cross sections for the six $2s2p(^1,3P)1s \ ^2,4P_J - 1s^22s \ ^2S_{1/2}$ transitions for the two Li-like ions (Ti^{19+} and Fe^{23+}). Our calculated data are compared with results calculated using the relativistic distorted -wave code of Zhang, Sampson and Clark [31] and experimental results measured on the Livermore electron beam ion trap. These measurements were made near the threshold (the scaled electron energy $u \approx 0.02$). The uncertainties in the

measurements are between 14 and 27% for Li-like transitions. The experimental data agree with two theoretical results within the error bars except for "u" line. It was underlined in [17] that this line is one of the most difficult transitions to measure. Theoretical results almost coincide for this line.

Comparison of excitation rare coefficients are given in Table 9 for the 14 lines of FeXXIV ion. We compare our data with data obtained by Bely-Dubau et al [4] calculated using the University College London computer package. The scattering problem is solved in this code by using the distorted wave approximation with configuration interaction. We can see from Table 9 that both theoretical results agree quite well except data for three lines: s,h and n. We could not explain disagreement in these two results for these three lines since there was not any difference between these three lines and another 11 lines for which we found the excellent agreement by two methods.

4. Conclusion

This paper has presented inner-shell collisional data for Li-like with $6 \leq Z \leq 42$. The $1/Z$ perturbation theory and Coulomb-Born- exchange approximation calculations performed here are less complicated than the relativistic distorted-wave approximation [31] but give good agreement with those results. This method can be applied for an arbitrary electron systems using the general formulae given in Appendix A.

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Appendix A. Intermediate coupling scheme for n-electron system

The excitation cross section for one-electron system can be represented in a form [25]

$$\delta(n_0 l_0, n_1 l_1) = \frac{16\pi a_0^2}{q^2} \frac{1}{(2l_0 + 1)} \sum_{\chi} \frac{1}{2\chi + 1} \left| P_{\chi}(q l_q n_0 l_0; n_1 l_1 k l_k) - \frac{1}{2} \sum_{\chi'} (2\chi + 1) (-1)^{\chi + \chi'} \begin{Bmatrix} l_1 & l_0 & \chi \\ l_k & l_q & \chi' \end{Bmatrix} P_{\chi'}(q l_q n_0 l_0; k l_k n_1 l_1) \right|^2 \quad (\text{A.1})$$

where

$$P_{\chi}(q l_q n_0 l_0; n_1 l_1 k l_k) = \sqrt{(2l_q + 1)(2l_0 + 1)(2l_k + 1)(2l_1 + 1)} \begin{pmatrix} \chi & l_q & l_k \\ 0 & 0 & 0 \end{pmatrix} \times \begin{pmatrix} \chi & l_0 & l_1 \\ 0 & 0 & 0 \end{pmatrix} \int_0^{\infty} dr_1 \int_0^{\infty} dr_2 \left[\frac{r_1^{\chi}}{r_1^{\chi+1}} - \frac{\delta(\chi, 0)}{r_1} \right] F_{q l_q}(r_1) P_{n_0 l_0}(r_2) F_{k l_k}(r_1) P_{n_1 l_1}(r_2) \quad (\text{A.2})$$

$$P_{\chi}(q l_q n_0 l_0; k l_k n_1 l_1) = \sqrt{(2l_q + 1)(2l_0 + 1)(2l_k + 1)(2l_1 + 1)} \begin{pmatrix} \chi & l_q & l_1 \\ 0 & 0 & 0 \end{pmatrix} \times \begin{pmatrix} \chi & l_0 & l_k \\ 0 & 0 & 0 \end{pmatrix} \int_0^{\infty} dr_1 \int_0^{\infty} dr_2 \left[\frac{r_1^{\chi}}{r_1^{\chi+1}} \right] F_{q l_q}(r_1) P_{n_0 l_0}(r_2) F_{k l_k}(r_2) P_{n_1 l_1}(r_1) \quad (\text{A.3})$$

For describing of n-electron system in intermediate coupling scheme let us first consider an amplitude of excitation in non-relativistic case [25]

$$P(QLSMM_S, Q'L'S'M'S_S) = \frac{1}{(n-1)!} \sum_{\alpha_1 \dots \alpha_n} \sum_{\alpha_n} C_{\alpha_1 \dots \alpha_n}^{QLS} C_{\alpha \dots \alpha_{n-1} \alpha_n}^{Q'L'S'} \left[V_{q\alpha_n; \alpha_n k} - V_{q\alpha_n; k\alpha_n} \right] \quad (\text{A.4})$$

where $\alpha_i = n_i l_i m_i m_s$ is one-electron quantum numbers and Q, Q' mean configuration and intermediate quantum numbers of atomic system: L_{12} and S_{12} (for example: $Q = j_1 j_2 [L_{12} S_{12}] j_3 [L_{13} S_{13}] j_4 [L_{14} S_{14}] \dots [L_{1n-1} S_{1n-1}] j_n$). Many-electron system should be described by linear combination of the zero order states belonging to the subspace of the degenerate levels. To provide orthonormality of the wave function the antisymmetric in all indexes coefficients C^Q must obey

$$\sum_{\alpha_1 \dots \alpha_n} C_{\alpha_1 \dots \alpha_n}^{*Q} C_{\alpha_1 \dots \alpha_n}^{Q'} = n! \delta(Q, Q') \quad (\text{A.5})$$

Matrix elements V can be represent in the factorization form for angular and radial (A.2, A.3) parts:

$$\begin{aligned} V_{q\alpha; \alpha'k} &= \sum_{\ell_q m_q} \sum_{\ell_k m_k} \sum_{\ell m} i^{\ell_q - \ell_k} Y_{\ell_q m_q}(\theta_q, \varphi_q) Y_{\ell_k m_k}^*(\theta_k, \varphi_k) (-1)^{m_q + m_{\alpha} + m} \delta(m_{s_q}, m_{s_{\alpha'}}) \\ &\times \delta(m_{s_q}, m_{s_{q'}}) \begin{pmatrix} \ell_q & \ell_k & \ell \\ -m_q & m_k & m \end{pmatrix} \begin{pmatrix} \ell_{\alpha} & \ell_{\alpha'} & \ell \\ -m_{\alpha} & m_{\alpha'} & -m \end{pmatrix} P_{\ell}(q \ell_q n_{\alpha} \ell_{\alpha}; n_{\alpha'}, \ell_{\alpha'}, k \ell_k) \end{aligned} \quad (\text{A.6})$$

$$\begin{aligned} V_{q\alpha; k\alpha'} &= \sum_{\ell_k m_k} \sum_{\ell_q m_q} \sum_{\ell m} (i)^{\ell_k - \ell_q} Y_{\ell_q m_q}(\theta_q, \varphi_q) Y_{\ell_k m_k}^*(\theta_k, \varphi_k) (-1)^{m_q + m_{\alpha} + m} \delta(m_{s_q}, m_{s_{\alpha'}}) \\ &\times \delta(m_{s_k}, m_{s_{\alpha'}}) \begin{pmatrix} \ell_q & \ell_{\alpha'} & \ell \\ -m_q & m_{\alpha'} & m \end{pmatrix} \begin{pmatrix} \ell_{\alpha} & \ell_k & \ell \\ -m_{\alpha} & m_k & -m \end{pmatrix} P_{\ell}(q \ell_q n_{\alpha} \ell_{\alpha}; k \ell_k n_{\alpha'}, \ell_{\alpha'}) \end{aligned} \quad (\text{A.7})$$

where P_{ℓ} is defined by eqs.(A.2) and (A.3) accordingly. In the results of calculations we can obtain for $P(\text{QLSMM}_S, \text{Q}'\text{L}'\text{S}'\text{M}'\text{M}'_S)$:

$$\begin{aligned} P(\text{QLSMM}_S, \text{Q}'\text{L}'\text{S}'\text{M}'\text{M}'_S) &= \frac{1}{(n-1)!} \sum_{L_{12} S_{12} \dots L_{1n-1} S_{1n-1}} \sum_{\ell_q m_q \ell_k m_k} \sum_{\ell_1 \dots \ell_n} \sum_{\mu} \sum_{\ell} (-1)^{M' + m_q} \\ &\times Y(\ell_q m_q \theta_q \varphi_q, \ell_k m_k \theta_k \varphi_k) \begin{pmatrix} \ell_q & \ell_k & a \\ -m_q & m_k & \mu \end{pmatrix} \begin{pmatrix} L & L' & a \\ M & -M' & \mu \end{pmatrix} \sqrt{(2L+1)(2L'+1)} \\ &\times C_{\ell_1 j_1 \dots \ell_n j_n}(L_{12} S_{12}, L_{12}'' S_{12}'' \dots L S) C_{\ell_1 j_1 \ell_2 j_2 \dots \ell_{n-1} j_{n-1} \ell_n j_n}(L_{12}' S_{12}', L_{12}'' S_{12}'' \dots L' S') \\ &\times [\delta(a, \ell) \delta(m_{s_k}, m_{s_q}) \delta(M_S, M_S') \delta(S, S')] P_{\ell}(q \ell_q n_n \ell_n; n_n', \ell_n' k \ell_k) (-1)^{L_{n-1}} \begin{Bmatrix} L & L' & \ell \\ \ell_n' & \ell_n & L_{n-1} \end{Bmatrix} \\ &- P_{\ell}(q \ell_q n_n \ell_n; k \ell_k n_n' \ell_n') (2a+1) \begin{Bmatrix} \ell_n' & \ell_n & a \\ \ell_k & \ell_q & \ell \end{Bmatrix} \begin{Bmatrix} L & L' & a \\ \ell_n' & \ell_n & L_{n-1} \end{Bmatrix} \sqrt{(2S+1)(2S'+1)} \\ &\times (-1)^{a+\ell+L_{n-1}} \sum_{M_{S_{n-1}}} (-1)^{2S_{n-1}-I+M_S+M_S'} \begin{pmatrix} S_{n-1} & 1/2 & S \\ M_{S_{n-1}} & m_{s_q} & -M_S \end{pmatrix} \begin{pmatrix} S_{n-1} & 1/2 & S' \\ M_{S_{n-1}} & m_{s_q} & -M_{S'} \end{pmatrix} \end{aligned} \quad (\text{A.8})$$

where we use designations

$$Y(\ell_q m_q \theta_q \varphi_q, \ell_k m_k \theta_k \varphi_k) = i^{\ell_q - \ell_k} Y_{\ell_q m_q}(\theta_q \varphi_q) Y_{\ell_k m_k}^*(\theta_k \varphi_k) \quad (\text{A.9})$$

The amplitude of excitation in intermediate coupling scheme should be determine by $P(\text{QLSMM}_S, \text{Q}'\text{L}'\text{S}'\text{M}'\text{M}'_S)$ and intermediate mixing coefficients $C^J(\text{Q}_J \text{L}_J \text{S}_J, \text{QLS})$

$$\begin{aligned} P(\text{Q}_J \text{J} \text{M}_J, \text{Q}'_J \text{J}' \text{M}'_J) &= \sum_{\text{QLS}} \sum_{\text{Q}'\text{L}'\text{S}'\text{M}'\text{M}'_S} C^J(\text{Q}_J \text{L}_J \text{S}_J, \text{QLS}) C^{J'}(\text{Q}'\text{L}'\text{S}', \text{Q}'_J \text{L}'_J \text{S}'_J) \\ &\times (-1)^{L-S+M_J} \sqrt{(2J+1)} \begin{pmatrix} L & S & J \\ M & M_S & -M_J \end{pmatrix} (-1)^{L'-S'+M'_J} \sqrt{(2J'+1)} \begin{pmatrix} L' & S' & J' \\ M' & M'_S & -M'_J \end{pmatrix} \\ &\times P(\text{QLSMM}_S, \text{Q}'\text{L}'\text{S}'\text{M}'\text{M}'_S) \end{aligned} \quad (\text{A.10})$$

The intermediate mixing coefficients $C^J(\text{Q}_J \text{L}_J \text{S}_J, \text{QLS})$ should be calculated by diagonalizing the matrix of energy with taking into account the relativistic and correlation effects. These coefficients are discussed in the Part 3. After the simple but cumbersome calculations we found for the amplitude;

$$\begin{aligned} P(\text{Q}_J \text{J} \text{M}_J, \text{Q}'_J \text{J}' \text{M}'_J) &= \sum_{\ell_q m_q \ell_k m_k a \mu a_1 \mu_1 a_2 \mu_2} Y(\ell_q m_q \theta_q \varphi_q, \ell_k m_k \theta_k \varphi_k) (-1)^{m_q - m_{S_k} - 1/2} \\ &\times \begin{pmatrix} \ell_q & \ell_k & a \\ -m_q & m_k & \mu \end{pmatrix} \begin{pmatrix} J & a & a_1 \\ -M_J & -\mu & -\mu_1 \end{pmatrix} \begin{pmatrix} a_1 & J' & a_2 \\ \mu_1 & M'_J & \mu_2 \end{pmatrix} \begin{pmatrix} a_2 & 1/2 & 1/2 \\ -\mu_2 & -m_{S_q} & m_{S_k} \end{pmatrix} \\ &\times \sum_{\text{QLS}'\text{Q}'\text{L}'\text{S}'_J} C^J(\text{QLS}, \text{Q}_J \text{L}_J \text{S}_J) C^{J'}(\text{Q}'\text{L}'\text{S}', \text{Q}'_J \text{L}'_J \text{S}'_J) (-1)^{L_J - S + a + J} \\ &\times \frac{1}{(n-1)!} \sum_{L''_{12} S''_{12} \dots L''_{1n-1} S''_{1n-1}} \sum_{\ell'_1 \dots \ell'_n} \sum_{\ell'_n} C_{\ell'_1 j_1 \dots \ell'_n j_n} (L''_{12} S''_{12} L''_{12} S''_{12}, \dots, L''_{1n-1} S''_{1n-1} L''_{1n-1} S''_{1n-1}, L_J S_J) \\ &\times C_{\ell'_1 j'_1 \dots \ell'_n j'_n} (L'_{12} S'_{12} L'_{12} S'_{12}, \dots, L'_{1n-1} S'_{1n-1} L'_{1n-1} S'_{1n-1}, L'_J S'_J) \\ &\quad \sqrt{(2L+1)(2L'+1)(2J+1)(2J'+1)} \\ &\times \sum_{\ell} \left[\delta(a, \ell) \delta(a_2, 0) \sqrt{2(2J'+1)} \begin{Bmatrix} L & L' & \ell \\ \ell'_n & \ell_n & L''_{1n-1} \end{Bmatrix} \begin{Bmatrix} J & J' & a \\ L' & L & S \end{Bmatrix} P_{\ell}(\ell_1 n_n \ell_n; n'_n \ell'_n k \ell_3) \right. \\ &\quad \left. - (-1)^{\ell+a+2a_1+S+S'+2J+L'+S_J+J'+1/2} (2a+1)(2a_1+1)(2a_2+1) \sqrt{(2S+1)(2S'+1)} \right. \\ &\quad \times P_{\ell}(\ell_q n_n \ell_n; k \ell_k n'_n \ell'_n) \begin{Bmatrix} \ell'_n & \ell_n & a \\ \ell_k & \ell_q & \ell \end{Bmatrix} \begin{Bmatrix} \ell'_n & \ell_n & a \\ L & L' & L''_{1n-1} \end{Bmatrix} \\ &\quad \left. \times \begin{Bmatrix} J & a & a_1 \\ L' & S & L \end{Bmatrix} \begin{Bmatrix} a_1 & J' & a_2 \\ S' & S & L' \end{Bmatrix} \begin{Bmatrix} a_2 & 1/2 & 1/2 \\ S''_{1n-1} & S & S' \end{Bmatrix} \right] \end{aligned} \quad (\text{A.11})$$

The cross section of excitation in intermediate coupling scheme can be determine by usual way [25]

$$\begin{aligned} \alpha(j_1 j_2 [L_{12} S_{12}] j_3 \cdots L_J S_J J, j'_1 j'_2 [L'_{12}] j'_3 \cdots L'_J S'_J J') = \\ = \frac{A_0}{(2J+1)} \sum_{m_{S_q} m_{S_k}} \sum_{M_J M'_J} \int d\omega_k d\omega_q |P(Q_J J M_J, Q'_J J' M'_J)|^2 \end{aligned} \quad (\text{A.12})$$

where $A_0=8\pi(a_0)^2/q^2(2j_x+1)$. The dependence on ω is in Y defined by Eq.(A.9). By using this formula we can simple calculate the integrals in (A.12).

$$\begin{aligned} A_1 = \int d\omega_k d\omega_q Y(\ell_q m_q \theta_q \varphi_q, \ell_k m_k \theta_k \varphi_k) Y^*(\ell'_q m'_q \theta_q \varphi_q, \ell'_k m'_k \theta_k \varphi_k) \\ = \delta(\ell_q, \ell'_q) \delta(m_q, m'_q) \delta(\ell_k, \ell'_k) \delta(m_k, m'_k) \end{aligned} \quad (\text{A.13})$$

For calculations the cross section in intermediate coupling schemes it should be used the next formula:

$$\begin{aligned} A_2 = \sum_{\ell_1 m_1 \ell_3 m_3} \sum_{a \mu a_1 \mu_1 a_2 \mu_2} \sum_{a' \mu' a'_1 \mu'_1 a'_2 \mu'_2} \begin{pmatrix} \ell_1 & \ell_3 & a \\ -m_1 & m_3 & \mu \end{pmatrix} \begin{pmatrix} \ell_1 & \ell_3 & a \\ -m_1 & m_3 & \mu \end{pmatrix} \\ \times \sum_{M_J M'_J} \sum_{m_{S_q} m_{S_k}} \begin{pmatrix} J & a & a_1 \\ -M_J & -\mu & -\mu_1 \end{pmatrix} \begin{pmatrix} a_1 & J' & a_2 \\ \mu_1 & M_J & \mu_2 \end{pmatrix} \begin{pmatrix} a_2 & 1/2 & 1/2 \\ -\mu_2 & m_{S_q} & m_{S_k} \end{pmatrix} \\ \times \begin{pmatrix} J & a' & a'_1 \\ -M_J & -\mu' & -\mu'_1 \end{pmatrix} \begin{pmatrix} a'_1 & J' & a'_2 \\ \mu'_1 & M_J & \mu'_2 \end{pmatrix} \begin{pmatrix} a'_2 & 1/2 & 1/2 \\ -\mu'_2 & m_{S_q} & m_{S_k} \end{pmatrix} = \\ = \sum_{a \mu a_1 \mu_1 a_2 \mu_2} \sum_{a' \mu' a'_1 \mu'_1 a'_2 \mu'_2} \sum_{M_J M'_J} \delta(a, a') \delta(\mu, \mu') \frac{1}{(2a+1)} \frac{1}{(2a_2+1)} \delta(a_2, a'_2) \delta(\mu_2, \mu'_2) \\ \times \begin{pmatrix} J & a & a_1 \\ -M_J & -\mu & -\mu_1 \end{pmatrix} \begin{pmatrix} J & a & a'_1 \\ -M_J & -\mu & -\mu'_1 \end{pmatrix} \begin{pmatrix} a_1 & J' & a_2 \\ \mu_1 & M_J & \mu_2 \end{pmatrix} \begin{pmatrix} a'_1 & J' & a'_2 \\ \mu'_1 & M_J & \mu'_2 \end{pmatrix} = \\ = \sum_{a a_1 a_2} \sum_{\mu_1} \frac{1}{(2a+1)} \frac{1}{(2a_2+1)} \frac{1}{(2a_1+1)^2} = \sum_{a a_1 a_2} \frac{1}{(2a+1)} \frac{1}{(2a_1+1)} \frac{1}{(2a_2+1)} \end{aligned} \quad (\text{A.14})$$

After the simple but cumbersome calculations we found for the cross sections in intermediate coupling scheme:

$$\alpha(j_1 j_2 [L_{12} S_{12}] j_3 \cdots L_J S_J J, j'_1 j'_2 [L'_{12}] j'_3 \cdots L'_J S'_J J') = \frac{A_0}{(2J+1)} (R_1 + R_2 + R_3) \quad (\text{A.15})$$

where

$$R_1 = \sum_{\ell_q \ell_k} \sum_{\ell} \sum_{\ell_n \ell'_n \ell''_n \ell'''_n} 2P_{\ell}(q\ell_q n_n \ell_n; n'_n \ell'_n k\ell_k) P_{\ell}(q\ell_q n''_n \ell''_n; n'''_n \ell'''_n k\ell_k) \times \frac{1}{(2\ell+1)} S_{\ell}(n_n \ell_n, n'_n \ell'_n) S_{\ell}(n''_n \ell''_n, n'''_n \ell'''_n) \quad (\text{A.16})$$

$$R_2 = \sum_{\ell_q \ell_k} \sum_{\ell \ell'} \sum_a \sum_{\ell_n \ell'_n \ell''_n \ell'''_n} P_{\ell}(q\ell_q n_n \ell_n; k\ell_k n'_n \ell'_n) \begin{Bmatrix} \ell'_n & \ell_n & a \\ \ell_k & \ell_q & \ell \end{Bmatrix} \times P_{\ell'}(q\ell_q n''_n \ell''_n; k\ell_k n'''_n \ell'''_n) \begin{Bmatrix} \ell''_n & \ell'_n & a \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \quad (\text{A.17})$$

$$\times (-1)^{\ell+\ell'} \sum_{a_1 a_2} M_a^{a_1 a_2}(n_n \ell_n, n'_n \ell'_n) M_a^{a_1 a_2}(n''_n \ell''_n, n'''_n \ell'''_n)$$

$$R_3 = \sum_{\ell_q \ell_k} \sum_{\ell \ell'} \sum_{\ell_n \ell'_n \ell''_n \ell'''_n} 2P_{\ell}(q\ell_q n_n \ell_n; n'_n \ell'_n k\ell_k) P_{\ell'}(q\ell_q n''_n \ell''_n; k\ell_k n'''_n \ell'''_n) \begin{Bmatrix} \ell''_n & \ell'_n & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \times (-1)^{\ell+\ell'+1} S_{\ell}(n_n \ell_n, n'_n \ell'_n) S_{\ell'}(n''_n \ell''_n, n'''_n \ell'''_n) \quad (\text{A.18})$$

where the next designations were used:

$$S_{\ell}(n_n \ell_n, n'_n \ell'_n) = \frac{1}{(n-1)!} \sum_{QLS} \sum_{Q'L'S'} C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J) \times \sum_{L''_{12} S''_{12} \cdots L''_{1n-1} S''_{1n-1}} \sum_{\ell_1 \cdots \ell_{n-1}} C_{\ell_{1j_1} \cdots \ell_{n j_n}}(L_{12} S_{12} L''_{12} S''_{12}, \cdots, L_{1n-1} S_{1n-1} L''_{1n-1} S''_{1n-1}, LS) \times C_{\ell_{1j'_1} \cdots \ell_{n j'_n}}(L'_{12} S'_{12} L''_{12} S''_{12}, \cdots, L'_{1n-1} S'_{1n-1} L''_{1n-1} S''_{1n-1}, L'S') \times f_{\ell}(\ell_n \ell'_n; LSJ, L'S'J'; L''_{1n-1}) \quad (\text{A.19})$$

$$f_{\ell}(\ell_n \ell'_n; LSJ, L'S'J', L''_{1n-1}) = (-1)^{L''_{1n-1}} \sqrt{(2L+1)(2L'+1)} \begin{Bmatrix} L & L' & \ell \\ \ell'_n & \ell_n & L''_{1n-1} \end{Bmatrix} \times (-1)^{-S+\ell+J} \delta(S, S') \sqrt{(2J+1)(2J'+1)} \begin{Bmatrix} J & J' & \ell \\ L' & L & S \end{Bmatrix}$$

(A.20)

$$\begin{aligned}
M_a^{a_1 a_2}(\mathbf{n}_n \ell_n, \mathbf{n}'_n \ell'_n) &= \frac{1}{(n-1)!} \sum_{QLSQ'L'S'} \sum C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J) \\
&\times \sum_{L''_{12} S''_{12} \dots L''_{1n-1} S''_{1n-1}} \sum_{\ell_1 \dots \ell_{n-1}} C_{\ell_1 j_1 \dots \ell_n j_n} (L_{12} S_{12} L''_{12} S''_{12}, \dots, L_{1n-1} S_{1n-1} L''_{1n-1} S''_{1n-1}, LS) \\
&\times C_{\ell_1 j_1 \dots \ell_n j_n} (L'_{12} S'_{12} L''_{12} S''_{12}, \dots, L'_{1n-1} S'_{1n-1} L''_{1n-1} S''_{1n-1}, L'S') \\
&\times f_a^{a_1 a_2}(\ell_n \ell'_n; LSJ, L'S'J'; L''_{1n-1} S''_{1n-1})
\end{aligned} \tag{A.21}$$

$$\begin{aligned}
f_a^{a_1 a_2}(\ell_n \ell'_n; LSJ, L'S'J'; L''_{1n-1} S''_{1n-1}) &= \\
&(-1)^{a+L''_{1n-1}+S''_{1n-1}} \sqrt{(2a+1)(2L+1)(2L'+1)} \begin{Bmatrix} L & L' & a \\ \ell_n & \ell_n & L''_{1n-1} \end{Bmatrix} \begin{Bmatrix} a_2 & 1/2 & 1/2 \\ S''_{1n-1} & S & S' \end{Bmatrix} \\
&\times (-1)^{2a_1-J+J'+a+L'+S'+1/2'} \sqrt{(2a_1+1)(2a_2+1)(2J+1)(2J'+1)(2S+1)(2S'+1)} \\
&\times \begin{Bmatrix} J & a & a_1 \\ L' & S & L \end{Bmatrix} \begin{Bmatrix} a_1 & J' & a_2 \\ S' & S & L' \end{Bmatrix}
\end{aligned} \tag{A.22}$$

It should be noted that the index a_2 in (A.22) can be equal to 0 or 1 (triangle'e rule for 6-j Wigner coefficient). In this case we can remove one sum in (A.17)

$$\mathfrak{R} = \sum_{a_1 a_2} M_a^{a_1 a_2}(\mathbf{n}_n \ell_n, \mathbf{n}'_n \ell'_n) M_a^{a_1 a_2}(\mathbf{n}''_n \ell''_n, \mathbf{n}'''_n \ell'''_n) = \mathfrak{R}^0 + \mathfrak{R}^1$$

$$\begin{aligned}
\mathfrak{R}^0 &= \sum_{a_1} M_a^{a_1 0}(\mathbf{n}_n \ell_n, \mathbf{n}'_n \ell'_n) M_a^{a_1 0}(\mathbf{n}''_n \ell''_n, \mathbf{n}'''_n \ell'''_n), \\
\mathfrak{R}^1 &= \sum_{a_1} M_a^{a_1 1}(\mathbf{n}_n \ell_n, \mathbf{n}'_n \ell'_n) M_a^{a_1 1}(\mathbf{n}''_n \ell''_n, \mathbf{n}'''_n \ell'''_n)
\end{aligned} \tag{A.23}$$

After simple but cumbersome calculations we found

$$M_a^{a_1 0}(\mathbf{n}_n \ell_n, \mathbf{n}'_n \ell'_n) = S_a(\mathbf{n}_n \ell_n, \mathbf{n}'_n \ell'_n) \delta(a_1, J') \sqrt{(2a+1)/2} \tag{A.24}$$

and

$$\mathfrak{R}^0 = \frac{2a+1}{2} S_a(n_n l_n, n'_n l'_n) S_a(n''_n l''_n, n'''_n l'''_n) \quad (\text{A.25})$$

By using this equations we can rewrite σ in the next form:

$$\begin{aligned} \alpha(j_1 j_2 [L_{12} S_{12}] j_3 \cdots L_J S_J J, j'_1 j'_2 [L'_{12} S'_{12}] j'_3 \cdots L'_J S'_J J') &= \frac{A_0}{(2J+1)} \\ &\times \sum_{\ell_q \ell_k} \sum_{\ell} \left| \sum_{n_n l_n n'_n l'_n} S_{\ell}(n_n l_n, n'_n l'_n) \left(\sqrt{\frac{2}{2\ell+1}} P_{\ell}(q l_q n_n l_n; n'_n l'_n k l_k) \right. \right. \\ &\quad \left. \left. - \sqrt{\frac{2\ell+1}{2}} \sum_{\ell'} (-1)^{\ell+\ell'} \begin{Bmatrix} \ell'_n & \ell_n & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} P_{\ell'}(q l_q n_n l_n; k l_k n'_n l'_n) \right) \right|^2 \\ &+ \frac{A_0}{(2J+1)} \sum_{\ell_k \ell_q} \sum_{\ell} \sum_{a_1} \left| \sum_{\ell'} \sum_{n_n l_n n'_n l'_n} M_{\ell}^{a_1}(n_n l_n, n'_n l'_n) (-1)^{\ell+\ell'} \begin{Bmatrix} \ell'_n & \ell_n & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \right. \\ &\quad \left. \times P_{\ell'}(q l_q n_n l_n; k l_k n'_n l'_n) \right|^2 \end{aligned} \quad (\text{A.26})$$

where

$$\begin{aligned} M_{\ell}^{a_1}(n_n l_n, n'_n l'_n) &= \frac{1}{(n-1)!} \sum_{QLSQ'L'S'} C^J(QLS, Q_J L_J S_J) C^{J'}(Q' L' S', Q'_J L'_J S'_J) \\ &\times \sum_{L''_{12} S''_{12} \cdots L''_{1n-1} S''_{1n-1}} \sum_{\ell_1 \cdots \ell_{n-1}} C_{\ell_1 j_1 \cdots \ell_{n-1} j_{n-1}}(L_{12} S_{12} L''_{12} S''_{12}, \cdots, L_{1n-1} S_{1n-1} L''_{1n-1} S''_{1n-1}, LS) \\ &\quad \times C_{\ell'_1 j'_1 \cdots \ell'_{n-1} j'_{n-1}}(L'_{12} S'_{12} L''_{12} S''_{12}, \cdots, L'_{1n-1} S'_{1n-1} L''_{1n-1} S''_{1n-1}, L'S') \\ &\quad f_{\ell}^{a_2}(\ell_n l'_n; LSJ, L'S'J'; L''_{1n-1} S''_{1n-1}) \end{aligned} \quad (\text{A.27})$$

$$\begin{aligned} f_{\ell}^{a_1}(\ell_n l'_n; LSJ, L'S'J'; L''_{1n-1} S''_{1n-1}) &= (-1)^{2a_1 + L''_{1n-1} + S''_{1n-1} + L' + S' - J + J' + 1/2} \\ &\times \sqrt{3(2\ell+1)(2a_1+1)(2L+1)(2L'+1)(2J+1)(2J'+1)(2S+1)(2S'+1)} \\ &\times \begin{Bmatrix} L & L' & \ell \\ \ell'_n & \ell_n & L''_{1n-1} \end{Bmatrix} \begin{Bmatrix} 1 & 1/2 & 1/2 \\ S''_{1n-1} & S & S' \end{Bmatrix} \begin{Bmatrix} J & \ell & a_1 \\ L' & S & L \end{Bmatrix} \begin{Bmatrix} a_1 & J' & 1 \\ S' & S & L' \end{Bmatrix} \end{aligned} \quad (\text{A.28})$$

Let us investigate the excitation of a system with two electrons above core. For this special case we can find for σ :

$$\begin{aligned}
\alpha(j_1 j_2 L_J S_J J, j'_1 j'_2 L'_J S'_J J') &= \frac{A_0}{(2J+1)!} \sum_{\ell_q \ell_k} \sum_{\ell} \left| \sum_{n_2 \ell_2 n'_2 \ell'_2} \sum_{QLS} \sum_{Q'L'S'} C^J(QLS, Q_J L_J S_J) \right. \\
&\quad \times C^{J'}(Q'L'S', Q'_J L'_J S'_J) \sum_{\ell_1} C_{\ell_1 j_1 \ell_2 j_2}(\text{LS}) C_{\ell_1 j'_1 \ell'_2 j'_2}(\text{L}'S') f_{\ell}(\ell_2 \ell'_2; \text{LSJ}, \text{L}'S'J'; \ell_1) \\
&\quad \times \left(\sqrt{\frac{2}{2\ell+1}} P_{\ell}(q \ell_q n_2 \ell_2; n'_2 \ell'_2 k \ell_k) - \sqrt{\frac{2\ell+1}{2}} \sum_{\ell'} (-1)^{\ell+\ell'} P_{\ell'}(q \ell_q n_2 \ell_2; k \ell_k n'_2 \ell'_2) \right. \\
&\quad \quad \left. \times \left. \begin{Bmatrix} \ell'_2 & \ell_2 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \right)^2 \right. \\
&+ \frac{A_0}{(2J+1)!} \sum_{\ell_q \ell_k} \sum_{\ell} \sum_{a_1} \left| \sum_{\ell'} \sum_{n_2 \ell_2 n'_2 \ell'_2} \sum_{QLS} \sum_{Q'L'S'} C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J) \right. \\
&\quad \times \sum_{\ell_1} C_{\ell_1 j_1 \ell_2 j_2}(\text{LS}) C_{\ell_1 j'_1 \ell'_2 j'_2}(\text{L}'S') f_{\ell}^{a_1}(\ell_2 \ell'_2; \text{LSJ}, \text{L}'S'J'; \ell_1 \frac{1}{2}) \\
&\quad \times (-1)^{\ell+\ell'} P_{\ell'}(q \ell_q n_2 \ell_2; k \ell_k n'_2 \ell'_2) \left. \left. \begin{Bmatrix} \ell'_2 & \ell_2 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \right)^2 \right.
\end{aligned} \tag{A.29}$$

where

$$\begin{aligned}
f_{\ell}(\ell_2 \ell'_2; \text{LSJ}, \text{L}'S'J'; \ell_1) &= (-1)^{\ell_1 + \ell - S + J} \delta(S, S') \begin{Bmatrix} L & L' & \ell \\ \ell'_2 & \ell_2 & \ell_1 \end{Bmatrix} \begin{Bmatrix} J & J' & \ell \\ L' & L & S \end{Bmatrix} \\
&\quad \times \sqrt{(2L+1)(2L'+1)(2J+1)(2J'+1)}
\end{aligned} \tag{A.30}$$

$$\begin{aligned}
f_{\ell}^{a_2}(\ell_2 \ell'_2; \text{LSJ}, \text{L}'S'J'; \ell_1 \frac{1}{2}) &= (-1)^{2a_1 + \ell_1 + 1 + L' + S' - J + J'} \begin{Bmatrix} L & L' & \ell \\ \ell'_2 & \ell_2 & \ell_1 \end{Bmatrix} \begin{Bmatrix} 1 & 1/2 & 1/2 \\ 1/2 & S & S' \end{Bmatrix} \\
&\quad \times \begin{Bmatrix} J & \ell & a_1 \\ L' & S & L \end{Bmatrix} \begin{Bmatrix} a_1 & J' & 1 \\ S' & S & L' \end{Bmatrix} \sqrt{3(2\ell+1)(2a_1+1)} \\
&\quad \times \sqrt{(2L+1)(2L'+1)(2S+1)(2S'+1)(2J+1)(2J'+1)}
\end{aligned} \tag{A.31}$$

Let us use two designations else in order to represent eq.(A.26) in more compact form:

$$\begin{aligned} \mathfrak{R}_\ell(q\ell_q n_2 \ell_2; n'_2 \ell'_2 k\ell_k) &= \sqrt{\frac{2}{2\ell+1}} P_\ell(q\ell_q n_2 \ell_2; n'_2 \ell'_2 k\ell_k) \\ &\quad - \sqrt{\frac{2\ell+1}{2}} \sum_{\ell'} (-1)^{\ell+\ell'} \left\{ \begin{matrix} \ell'_2 & \ell_2 & \ell \\ \ell_k & \ell_q & \ell' \end{matrix} \right\} P_{\ell'}(q\ell_q n_2 \ell_2; k\ell_k n'_2 \ell'_2) \end{aligned} \quad (\text{A.32})$$

$$\mathfrak{R}_\ell(q\ell_q n_2 \ell_2; k\ell_k n'_2 \ell'_2) = \sum_{\ell'} (-1)^{\ell+\ell'} \left\{ \begin{matrix} \ell'_2 & \ell_2 & \ell \\ \ell_k & \ell_q & \ell' \end{matrix} \right\} P_{\ell'}(q\ell_q n_2 \ell_2; k\ell_k n'_2 \ell'_2) \quad (\text{A.33})$$

Using these designations we obtain for $\sigma(j_1 j_2 L_J S_J; j'_1 j'_2 L'_J S'_J)$

$$\begin{aligned} \alpha(j_1 j_2 L_J S_J, j'_1 j'_2 L'_J S'_J) &= \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \left| \sum_{n_2 \ell_2 n'_2 \ell'_2} \sum_{QLS} \sum_{Q'L'S'} C^J(QLS, Q_J L_J S_J) \right. \\ &\quad \times C^{J'}(Q'L'S', Q'_J L'_J S'_J) \sum_{\ell_1} C_{\ell_1 j_1 \ell_2 j_2}(LS) C_{\ell_1 j'_1 \ell'_2 j'_2}(L'S') \\ &\quad \left. \times f_\ell(\ell_2 \ell'_2; LSJ, L'S'J'; \ell_1) \mathfrak{R}_\ell(q\ell_q n_2 \ell_2; n'_2 \ell'_2 k\ell_k) \right|^2 \\ &+ \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \sum_{a_1} \left| \sum_{n_2 \ell_2 n'_2 \ell'_2} \sum_{QLS} \sum_{Q'L'S'} C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J) \right. \\ &\quad \times \sum_{\ell_1} C_{\ell_1 j_1 \ell_2 j_2}(LS) C_{\ell_1 j'_1 \ell'_2 j'_2}(L'S') \\ &\quad \left. \times f_\ell^{a_1}(\ell_2 \ell'_2; LSJ, L'S'J'; \ell_1 \frac{1}{2}) \mathfrak{R}_\ell(q\ell_q n_2 \ell_2; k\ell_k n'_2 \ell'_2) \right|^2 \end{aligned} \quad (\text{A.34})$$

Sums over $n_2 \ell_2$, $n'_2 \ell'_2$ and ℓ_1 can be simple calculated by using the definition for C

$$C_{\ell_1 j_1 \ell_2 j_2}(LS) = N(j_1 j_2) (\delta(\ell_1, j_1) \delta(\ell_2, j_2) + (-1)^{L+S+j_1+j_2} \delta(\ell_1, j_2) \delta(\ell_2, j_1)) \quad (\text{A.35})$$

where $N(j_1 j_2) = 1$ if $j_1 \neq j_2$ or $N(j_1 j_2) = 1/\sqrt{2}$ if $j_1 = j_2$. It should be noted that we wrote in eq.(A.35) only the angular quantum numbers in order do not encumber this formula. After simple but cumbersome calculations we obtain

for $\sigma(j_1 j_2 L_J S_J J, j'_1 j'_2 L'_J S'_J J')$

$$\begin{aligned}
\sigma(j_1 j_2 L_J S_J J, j'_1 j'_2 L'_J S'_J J') &= \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \left[\sum_{QLS Q'L'S'} \sum C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J) \right. \\
&\quad \times N(j_1 j_2) N(j'_1 j'_2) \left(\delta(j_1, j'_1) f_{\ell}(j_2 j'_2; LSJ, L'S'J'; j_1) \mathfrak{R}_{\ell}(q_{\ell} n_2 j_2; n'_2 j'_2 k_{\ell} k) \right. \\
&\quad + (-1)^{L+S'+j_2+j'_1} \delta(j_1, j'_2) f_{\ell}(j_2 j'_1; LSJ, L'S'J'; j_1) \mathfrak{R}_{\ell}(q_{\ell} n_2 j_2; n'_2 j'_1 k_{\ell} k) \\
&\quad + (-1)^{L+S'+j_2+j'_1} \delta(j_2, j'_1) f_{\ell}(j_1 j'_2; LSJ, L'S'J'; j_2) \mathfrak{R}_{\ell}(q_{\ell} n_2 j_1; n'_2 j'_2 k_{\ell} k) \\
&\quad \left. \left. + (-1)^{L+S'+L'+S'+j_2+j'_1+j'_2+j'_1} \delta(j_2, j'_2) f_{\ell}(j_1 j'_1; LSJ, L'S'J'; j_2) \mathfrak{R}_{\ell}(q_{\ell} n_2 j_1; n'_2 j'_1 k_{\ell} k) \right) \right]^2 \\
&+ \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \sum_{a_1} \left[\sum_{QLS Q'L'S'} \sum C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J) \right. \\
&\quad \times N(j_1 j_2) N(j'_1 j'_2) \left(\delta(j_1, j'_1) f_{\ell}^{a_1}(j_2 j'_2; LSJ, L'S'J'; j_1 \frac{1}{2}) \mathfrak{R}_{\ell}(q_{\ell} n_2 j_2; k_{\ell} k n'_2 j'_2) \right. \\
&\quad + (-1)^{L+S'+j_2+j'_1} \delta(j_1, j'_2) f_{\ell}^{a_1}(j_2 j'_1; LSJ, L'S'J'; j_1 \frac{1}{2}) \mathfrak{R}_{\ell}(q_{\ell} n_2 j_2; k_{\ell} k n'_2 j'_1) \\
&\quad + (-1)^{L+S'+j_2+j'_1} \delta(j_2, j'_1) f_{\ell}^{a_1}(j_1 j'_2; LSJ, L'S'J'; j_2 \frac{1}{2}) \mathfrak{R}_{\ell}(q_{\ell} n_2 j_1; k_{\ell} k n'_2 j'_2) \\
&\quad \left. \left. + (-1)^{L+S'+L'+S'+j_2+j'_1+j'_2+j'_1} \delta(j_2, j'_2) f_{\ell}^{a_1}(j_1 j'_1; LSJ, L'S'J'; j_2 \frac{1}{2}) \mathfrak{R}_{\ell}(q_{\ell} n_2 j_1; k_{\ell} k n'_2 j'_1) \right) \right]^2
\end{aligned} \tag{36}$$

We can choose, for example, that $j_1 = j'_1$. In this case eq.(36) can be written in more short form:

$$\begin{aligned}
\sigma(j_1 j_2 L_J S_J J, j_1 j'_2 L'_J S'_J J') &= \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \left[\sum_{QLS Q'L'S'} \sum C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J) \right. \\
&\quad \times N(j_1 j_2) N(j_1 j'_2) f_{\ell}(j_2 j'_2; LSJ, L'S'J'; j_1) \mathfrak{R}_{\ell}(q_{\ell} n_2 j_2; n'_2 j'_2 k_{\ell} k) \left. \right]^2 \\
&+ \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \sum_{a_1} \left[\sum_{QLS Q'L'S'} \sum C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J) \right. \\
&\quad \times N(j_1 j_2) N(j_1 j'_2) f_{\ell}^{a_1}(j_2 j'_2; LSJ, L'S'J'; j_1 \frac{1}{2}) \mathfrak{R}_{\ell}(q_{\ell} n_2 j_2; k_{\ell} k n'_2 j'_2) \left. \right]^2
\end{aligned} \tag{A.37}$$

Appendix B. Intermediate coupling scheme for three-electron system

Let us investigate the excitation cross section for a system with three electrons above core. For this special case we can find from eq.(A.26):

$$\begin{aligned}
 \sigma(j_1 j_2 [L_{12} S_{12}] j_3 L_J S_J J, j_1' j_2' [L'_{12} S'_{12}] j_3' L'_J S'_J J') = & \\
 = \frac{A_0}{(2J+1)} \sum_{\ell_q \ell_k} \sum_{\ell} \left| \sum_{n_3 \ell_3 n_3' \ell_3'} \sum_{QLSQ'L'S'} C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J) \right. & \\
 \times \frac{1}{2} \sum_{L''_{12} S''_{12}} \sum_{\ell_1 \ell_2} C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3} (L_{12} S_{12}, L''_{12} S''_{12}; LS) C_{\ell_1 j_1' \ell_2 j_2' \ell_3 j_3'} (L'_{12} S'_{12}, L''_{12} S''_{12}; L'S') & \\
 f_{\ell}(\ell_3 \ell_3'; LSJ, L'S'J'; L''_{12}) P_{\ell}(q \ell_q n_3 \ell_3; n_3' \ell_3' k \ell_k) & \\
 \times \left(\frac{2}{2\ell+1} P_{\ell}(q \ell_q n_3 \ell_3; n_3' \ell_3' k \ell_k) - \sum_{\ell'} (-1)^{\ell+\ell'} P_{\ell'}(q \ell_q n_3 \ell_3; k \ell_k n_3' \ell_3') \begin{Bmatrix} \ell_3' & \ell_3 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \right)^2 & \\
 + \frac{A_0}{(2J+1)} \sum_{\ell_q \ell_k} \sum_{\ell} \sum_{a_1 a_2} \left| \sum_{\ell'} \sum_{n_3 \ell_3 n_3' \ell_3'} \sum_{QLSQ'L'S'} C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J) \right. & \\
 \times \frac{1}{2} \sum_{L''_{12} S''_{12}} \sum_{\ell_1 \ell_2} C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3} (L_{12} S_{12}, L''_{12} S''_{12}; LS) C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3} (LS, L''_{12} S''_{12}; L'S') & \\
 \times f_{\ell}^{a_1 a_2}(\ell_3 \ell_3'; LSJ, L'S'J'; L''_{12}) (-1)^{\ell+\ell'} P_{\ell'}(q \ell_q n_3 \ell_3; k \ell_k n_3' \ell_3') \begin{Bmatrix} \ell_3' & \ell_3 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \Bigg|^2 & \\
 & \tag{B.1}
 \end{aligned}$$

where (see eqs.(A.20) and (A.22))

$$\begin{aligned}
 f_{\ell}(\ell_3 \ell_3'; LSJ, L'S'J', L''_{12}) = & (-1)^{L''_{12}} \sqrt{(2L+1)(2L'+1)} \begin{Bmatrix} L & L' & \ell \\ \ell_3' & \ell_3 & L''_{12} \end{Bmatrix} \\
 \times & (-1)^{-S+\ell+J} \delta(S, S') \sqrt{(2J+1)(2J'+1)} \begin{Bmatrix} J & J' & \ell \\ L' & L & S \end{Bmatrix} \\
 & \tag{B.2}
 \end{aligned}$$

$$f_{\ell}^{a_1 a_2}(\ell_3 \ell'_3; LSJ, L'S'J'; L''_{12} S''_{12}) = (-1)^{2\ell+2a_1+L''_{12}+S''_{12}-J+J'+L'+S'+1/2}$$

$$\times \sqrt{(2\ell+1)(2a_1+1)(2a_2+1)(2L+1)(2L'+1)(2S+1)(2S'+1)(2J+1)(2J'+1)}$$

$$\times \left\{ \begin{array}{ccc} L & L' & \ell \\ \ell'_3 & \ell_3 & L''_{12} \end{array} \right\} \left\{ \begin{array}{ccc} a_2 & 1/2 & 1/2 \\ S''_{12} & S & S' \end{array} \right\} \left\{ \begin{array}{ccc} J & \ell & a_1 \\ L' & S & L \end{array} \right\} \left\{ \begin{array}{ccc} a_1 & J' & a_2 \\ S' & S & L' \end{array} \right\}$$

(B.3)

Coefficients $C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3}(L_{12} S_{12}, L''_{12} S''_{12}; LS)$ determine coupling scheme for three electrons system (j_1, j_2, j_3) with intermediate quantum numbers $L_{12} S_{12}$

$$C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3}(L_{12} S_{12}, L''_{12} S''_{12}; LS) = N(j_1 j_2 j_3)$$

$$\times \left[\delta(L_{12}, L''_{12}) \delta(S_{12}, S''_{12}) P_{L''_{12} S''_{12}}(\ell_1 j_1, \ell_2 j_2) \delta(\ell_3, j_3) \right.$$

$$+ \sqrt{(2L_{12}+1)(2S_{12}+1)(2L''_{12}+1)(2S''_{12}+1)} \left\{ \begin{array}{ccc} 1/2 & S''_{12} & 1/2 \\ 1/2 & S_{12} & S \end{array} \right\}$$

$$\times \left(P_{L''_{12} S''_{12}}(\ell_1 j_3, \ell_2 j_2) \delta(\ell_3, j_1) \left\{ \begin{array}{ccc} j_3 & j_2 & L''_{12} \\ j_1 & L & L_{12} \end{array} \right\} \right.$$

$$\left. - P_{L''_{12} S''_{12}}(\ell_1 j_3, \ell_2 j_1) \delta(\ell_3, j_2) (-1)^{j_1+j_2+L_{12}+S_{12}} \left\{ \begin{array}{ccc} j_3 & j_1 & L''_{12} \\ j_2 & L & L_{12} \end{array} \right\} \right)$$

(B.4)

where P defines two-electron system and equal to

$$P_{L''_{12} S''_{12}}(\ell_1 j_1, \ell_2 j_2) = \delta(\ell_1, j_1) \delta(\ell_2, j_2) + \delta(\ell_1, j_2) \delta(\ell_2, j_1)$$

(B.5)

A normalized factor $N(j_1 j_2 j_3)$ is determined by an equation (see eq.(A.5))

$$\sum_{L_{12} S_{12}} \sum_{\ell_1 \ell_2 \ell_3} \left[C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3}(L_{12} S_{12}, L''_{12} S''_{12}; LS) \right]^2 = 6$$

(B.6)

As a result $N(j_1 j_2 j_3)=1$ for all different j_1, j_2 and j_3 and $N(j_1 j_2 j_3)=1/\sqrt{2}$ when two of indexes j_k are coincided ($N(j_1 j_1 j_3)=N(j_1 j_2 j_2)=N(j_3 j_2 j_3)=1/\sqrt{2}$). Let us consider

$$\frac{1}{2} \sum_{\ell_1 \ell_2} C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3}(L_{12} S_{12}, L''_{12} S''_{12}; LS) C_{\ell_1 j'_1 \ell_2 j'_2 \ell_3 j'_3}(LS, L''_{12} S''_{12}; L' S')$$

(B.7)

After simple but cumbersome calculations we obtain for this expression

$$\frac{1}{2} \sum_{\ell_1 \ell_2} C_{\ell_1 \dot{j}_1 \ell_2 \dot{j}_2 \ell_3 \dot{j}_3} (L_{12} S_{12}, L_{12}'' S_{12}''; LS) C_{\ell_1 \dot{j}'_1 \ell_2 \dot{j}'_2 \ell_3 \dot{j}'_3} (L_{12}' S_{12}', L_{12}'' S_{12}''; L' S') =$$

$$= N(j_1 j_2 j_3) N(\dot{j}_1 \dot{j}_2 \dot{j}_3) [A_1 + A_2 + A_3] \quad (\text{B.8})$$

where

$$A_2 = \delta(L_{12}, L_{12}'') \delta(S_{12}, S_{12}'') \sqrt{(2L_{12}' + 1)(2S_{12}' + 1)(2L_{12}'' + 1)(2S_{12}'' + 1)}$$

$$\times \begin{Bmatrix} 1/2 & S_{12}'' & 1/2 \\ 1/2 & S_{12}' & S' \end{Bmatrix} \left[P_{L_{12}'' S_{12}''} (j_1 j_2, \dot{j}_3 \dot{j}_2') \delta(\ell_3, j_3) \delta(\ell_3', j_1') \begin{Bmatrix} \dot{j}_3 & \dot{j}_2 & L_{12}'' \\ \dot{j}_1 & L' & L_{12}'' \end{Bmatrix} \right.$$

$$\left. + P_{L_{12}'' S_{12}''} (j_1 j_2, \dot{j}_3 \dot{j}_2') \delta(\ell_3, j_3) \delta(\ell_3', j_2') \begin{Bmatrix} \dot{j}_3 & \dot{j}_1 & L_{12}'' \\ \dot{j}_2 & L' & L_{12}'' \end{Bmatrix} (-1)^{\dot{j}_1 + \dot{j}_2 + L_{12}'' + S_{12}''} \right]$$

$$+ \delta(L_{12}', L_{12}''') \delta(S_{12}', S_{12}''') \sqrt{(2L_{12} + 1)(2S_{12} + 1)(2L_{12}'' + 1)(2S_{12}'' + 1)} \begin{Bmatrix} 1/2 & S_{12}'' & 1/2 \\ 1/2 & S_{12} & S \end{Bmatrix}$$

$$\times \left[P_{L_{12}'' S_{12}''} (j_3 j_2, \dot{j}_1 \dot{j}_2') \delta(\ell_3, j_1) \delta(\ell_3', j_3') \begin{Bmatrix} j_3 & j_2 & L_{12}'' \\ j_1 & L & L_{12}'' \end{Bmatrix} \right.$$

$$\left. + P_{L_{12}'' S_{12}''} (j_3 j_1, \dot{j}_1 \dot{j}_2') \delta(\ell_3, j_2) \delta(\ell_3', j_3') \begin{Bmatrix} j_3 & j_2 & L_{12}'' \\ j_1 & L & L_{12}'' \end{Bmatrix} (-1)^{\dot{j}_1 + \dot{j}_2 + L_{12}'' + S_{12}''} \right] \quad (\text{B.9})$$

$$A_3 = (2L_{12}'' + 1)(2S_{12}'' + 1) \sqrt{2L_{12} + 1)(2S_{12} + 1)(2L_{12}' + 1)(2S_{12}' + 1)}$$

$$\times \begin{Bmatrix} 1/2 & S_{12}'' & 1/2 \\ 1/2 & S_{12} & S \end{Bmatrix} \begin{Bmatrix} 1/2 & S_{12}'' & 1/2 \\ 1/2 & S_{12}' & S' \end{Bmatrix}$$

$$\times \left[P_{L_{12}'' S_{12}''} (j_3 j_2, \dot{j}_3 \dot{j}_2') \delta(\ell_3, j_1) \delta(\ell_3', j_1') \begin{Bmatrix} j_3 & j_2 & L_{12}'' \\ j_1 & L & L_{12}'' \end{Bmatrix} \begin{Bmatrix} \dot{j}_3 & \dot{j}_2 & L_{12}'' \\ \dot{j}_1 & L' & L_{12}'' \end{Bmatrix} \right.$$

$$+ P_{L_{12}'' S_{12}''} (j_3 j_2, \dot{j}_3 \dot{j}_1') \delta(\ell_3, j_1) \delta(\ell_3', j_2') \begin{Bmatrix} j_3 & j_2 & L_{12}'' \\ j_1 & L & L_{12}'' \end{Bmatrix} \begin{Bmatrix} \dot{j}_3 & \dot{j}_1 & L_{12}'' \\ \dot{j}_2 & L' & L_{12}'' \end{Bmatrix} (-1)^{\dot{j}_1 + \dot{j}_2 + L_{12}'' + S_{12}''}$$

$$+ P_{L_{12}'' S_{12}''} (j_3 j_1, \dot{j}_3 \dot{j}_2') \delta(\ell_3, j_2) \delta(\ell_3', j_1') \begin{Bmatrix} j_3 & j_1 & L_{12}'' \\ j_2 & L & L_{12}'' \end{Bmatrix} \begin{Bmatrix} \dot{j}_3 & \dot{j}_2 & L_{12}'' \\ \dot{j}_1 & L' & L_{12}'' \end{Bmatrix} (-1)^{\dot{j}_1 + \dot{j}_2 + L_{12}'' + S_{12}''}$$

$$+ P_{L_{12}'' S_{12}''} (j_3 j_1, \dot{j}_3 \dot{j}_1') \delta(\ell_3, j_2) \delta(\ell_3', j_2') \begin{Bmatrix} j_3 & j_1 & L_{12}'' \\ j_2 & L & L_{12}'' \end{Bmatrix} \begin{Bmatrix} \dot{j}_3 & \dot{j}_1 & L_{12}'' \\ \dot{j}_2 & L' & L_{12}'' \end{Bmatrix} \right]$$

$$\times (-1)^{\dot{j}_1 + \dot{j}_2 + \dot{j}_1 + \dot{j}_2 + L_{12}'' + S_{12}'' + L_{12}'' + S_{12}''} \quad (\text{B.10})$$

$$A_1 = \delta(L_{12}, L''_{12}) \delta(S_{12}, S''_{12}) \delta(L'_{12}, L''_{12}) \delta(S'_{12}, S''_{12}) P_{L''_{12} S''_{12}}(j_1 j_2, j'_1 j'_2) \times \delta(\ell_3, j_3) \delta(\ell'_3, j'_3) \quad (\text{B.11})$$

and

$$P_{LS}(j_1 j_2, j'_1 j'_2) = \left[\delta(j_1, j'_1) \delta(j_2, j'_2) + \delta(j_1, j'_2) \delta(j_2, j'_1) (-1)^{j_1 + j_2 + L + S} \right] \times \left[1 + (-1)^{j_1 + j_2 + j'_1 + j'_2} \right] \quad (\text{B.12})$$

It is possible to consider any case of electron excitation for three electron system by using this expression. In order to calculate the inner shell cross section of excitation ($1s^2 [^1S] 2s \ ^2S - 2p 2s [^1,3P] 1s \ ^2P$ and $1s^2 [^1S] 2l \ ^2l - 2l^2 [L'_{12} S'_{12}] 1s \ L'S'$) let us investigate more common cases: $j_1^0 j_1^0 [L_{12} S_{12}] j_2^0 LS - j_3^0 j_2^0 [L'_{12} S'_{12}] j_1^0 L'S'$ and $j_1^0 j_1^0 [L_{12} S_{12}] j_2^0 LS - j_2^0 j_2^0 [L'_{12} S'_{12}] j_1^0 L'S'$. We can see that only the A_3 term from eq.(B.8) gives contribution to these transitions. It should be noted that the two terms in A_3 (eq.(B.12)) contribute for the $j_1^0 j_1^0 [L_{12} S_{12}] j_2^0 LS - j_3^0 j_2^0 [L'_{12} S'_{12}] j_1^0 L'S'$ excitation (the first and third terms) and the four terms are equal each other for the $j_1^0 j_1^0 [L_{12} S_{12}] j_2^0 LS - j_2^0 j_2^0 [L'_{12} S'_{12}] j_1^0 L'S'$ excitation. The normalized factors (see eq.B.8) are equal to $1/\sqrt{2}$ for the first case and $1/2$ for the second one.

As a result we obtain for in the case of $j_1^0 j_1^0 [L_{12} S_{12}] j_2^0 LS - j_3^0 j_2^0 [L'_{12} S'_{12}] j_1^0 L'S'$ excitation $j_1 = j_2 = j_1^0, j_3 = j_2^0$ and $j'_1 = j_3^0, j'_2 = j_2^0, j'_3 = j_1^0$ and

$$\begin{aligned} & \frac{1}{2} \sum_{\ell_1 \ell_2} C_{\ell_1 j_1^0 \ell_2 j_1^0 \ell_3 j_2^0} (L_{12} S_{12}, L''_{12} S''_{12}; LS) C_{\ell_1 j_3^0 \ell_2 j_2^0 \ell_3 j_1^0} (L'_{12} S'_{12}, L''_{12} S''_{12}; L'S') = \\ & = (2L''_{12} + 1)(2S''_{12} + 1) \sqrt{2(2L_{12} + 1)(2S_{12} + 1)(2L'_{12} + 1)(2S'_{12} + 1)} \\ & \quad \times \left\{ \begin{array}{ccc} 1/2 & S''_{12} & 1/2 \\ 1/2 & S_{12} & S \end{array} \right\} \left\{ \begin{array}{ccc} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & S' \end{array} \right\} \left\{ \begin{array}{ccc} j_2^0 & j_1^0 & L''_{12} \\ j_1^0 & L & L_{12} \end{array} \right\} \left\{ \begin{array}{ccc} j_1^0 & j_2^0 & L''_{12} \\ j_3^0 & L' & L'_{12} \end{array} \right\} \\ & \quad \times \delta(\ell_3, j_1^0) \delta(\ell'_3, j_3^0) (-1)^{j_1^0 + j_2^0 + L''_{12} + S''_{12}} \quad (\text{B.13}) \end{aligned}$$

In the case of $j_1^0 j_1^0 [L_{12} S_{12}] j_2^0 LS - j_2^0 j_2^0 [L'_{12} S'_{12}] j_1^0 L'S'$ excitation

$j_1 = j_2 = j_1^0, j_3 = j_2^0$ and $j'_1 = j_2^0, j'_3 = j_1^0$ we obtain for sum over l_1, l_2

$$\frac{1}{2} \sum_{\ell_1 \ell_2} C_{\ell_1 j_1^0 \ell_2 j_1^0 \ell_3 j_2^0} (L_{12} S_{12}, L''_{12} S''_{12}; LS) C_{\ell_1 j_2^0 \ell_2 j_2^0 \ell_3 j_1^0} (L'_{12} S'_{12}, L''_{12} S''_{12}; L'S') =$$

$$\begin{aligned}
&= 2(2L''_{12} + 1)(2S''_{12} + 1)\sqrt{(2L_{12} + 1)(2S_{12} + 1)(2L'_{12} + 1)(2S'_{12} + 1)} \\
&\quad \times \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S_{12} & S \end{Bmatrix} \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \begin{Bmatrix} j_2^0 & j_1^0 & L''_{12} \\ j_1^0 & L & L_{12} \end{Bmatrix} \begin{Bmatrix} j_1^0 & j_2^0 & L''_{12} \\ j_2^0 & L' & L'_{12} \end{Bmatrix} \\
&\quad \times \delta(\ell_3, j_1^0)\delta(\ell'_3, j_2^0)(-1)^{j_1^0 + j_2^0 + L''_{12} + S''_{12}}
\end{aligned} \tag{B.14}$$

These formulas can be simplified in the case of $j_1^0 = 0$ and $L_{12} = 0, S_{12} = 0$, e.g.

$1s^2(^1S)nj$ for initial state. We obtained instead of eqs.(B.13) and (B.14):

$$\begin{aligned}
&\frac{1}{2} \sum_{\ell_1 \ell_2} C_{\ell_1 0 \ell_2 j_0 \ell_3 j_2^0} (00, L''_{12} S''_{12}; LS) C_{\ell_1 j_1^0 \ell_2 j_2^0 \ell_3 0} (L'_{12} S'_{12}, L''_{12} S''_{12}; L' S') = \\
&= \frac{1}{\sqrt{2}} (2S''_{12} + 1) \sqrt{2S'_{12} + 1} \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} (-1)^{j_2^0 + j_3^0 + L' + 1} \\
&\quad \times \delta(j_2^0, L) \delta(j_2^0, L''_{12}) \delta(L'_{12}, L') \delta(\ell_3, 0) \delta(\ell'_3, j_3^0)
\end{aligned} \tag{B.15}$$

$$\begin{aligned}
&\frac{1}{2} \sum_{\ell_1 \ell_2} C_{\ell_1 0 \ell_2 j_0 \ell_3 j_2^0} (00, L''_{12} S''_{12}; LS) C_{\ell_1 j_1^0 \ell_2 j_2^0 \ell_3 0} (L'_{12} S'_{12}, L''_{12} S''_{12}; L' S') = \\
&= (2S''_{12} + 1) \sqrt{2S'_{12} + 1} \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} (-1)^{L' + 1} \\
&\quad \times \delta(j_2^0, L) \delta(j_2^0, L''_{12}) \delta(L'_{12}, L') \delta(\ell_3, 0) \delta(\ell'_3, j_2^0)
\end{aligned} \tag{B.16}$$

Let us return to eq.(B.1) in order to investigate the next two terms in eq.(B.1)

$$\begin{aligned}
&X_\ell(\ell_3 \ell'_3; j_1 j_2 [L_{12} S_{12}] j_3 LSJ, j'_1 j'_2 [L'_{12} S'_{12}] j'_3 L' S' J) = \\
&\quad \times \frac{1}{2} \sum_{L''_{12} S''_{12}} \sum_{\ell_1 \ell_2} C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3} (L_{12} S_{12}, L''_{12} S''_{12}; LS) C_{\ell_1 j'_1 \ell_2 j'_2 \ell_3 j'_3} (LS, L''_{12} S''_{12}; L' S') \\
&\quad f_\ell(\ell_3 \ell'_3; LSJ, L' S' J; L''_{12})
\end{aligned} \tag{B.17}$$

$$\begin{aligned}
&Y_\ell^{a_1 a_2}(\ell_3 \ell'_3; j_1 j_2 [L_{12} S_{12}] j_3 LSJ, j'_1 j'_2 [L'_{12} S'_{12}] j'_3 L' S' J) = \\
&\quad \times \frac{1}{2} \sum_{L''_{12} S''_{12}} \sum_{\ell_1 \ell_2} C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3} (L_{12} S_{12}, L''_{12} S''_{12}; LS) C_{\ell_1 j'_1 \ell_2 j'_2 \ell_3 j'_3} (LS, L''_{12} S''_{12}; L' S') \\
&\quad f_\ell^{a_1 a_2}(\ell_3 \ell'_3; LSJ, L' S' J; L''_{12} S''_{12})
\end{aligned} \tag{B.18}$$

We already calculate sums over l_1 and l_2 for our two cases (see eq.(B.15) and (B.16)). It is not problem to sum over L''_{12} by taking delta function (see eq.(B.15) and (B.16)).In order to sum over S''_{12} we used the next formulas:

$$\sum_{S''_{12}} (2S''_{12} + 1) \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & 1/2 \end{Bmatrix} = \left\{ \frac{1}{2}, \frac{1}{2}, S'_{12} \right\} \quad (\text{B.19})$$

$$\sum_{S''_{12}} (2S''_{12} + 1) (-1)^{S''_{12}} \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & a_2 & S' \end{Bmatrix} = \begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \quad (\text{B.20})$$

$$\sum_{\chi} (2\chi + 1) \begin{Bmatrix} a & b & \chi \\ c & d & p \end{Bmatrix}^2 = \frac{1}{2p+1} \{a, d, p\} \{bcp\} \quad (\text{B.21})$$

The triangle rule in eq.(B.19) gives that S'_{12} can be equal to 0 or 1 only. In the result we find X and Y for our two special cases of excitations of $1s^2[{}^1S]nj$ states

$$\begin{aligned} X_{\ell}(\ell_3 \ell'_3; 1s^2[{}^1S]j_2^0 \text{LSJ}, j_3^0 j_2^0 [L'_{12} S'_{12}] | 1s L' S' J) = \\ = \sqrt{\frac{(2S'_{12} + 1)(2L' + 1)(2J + 1)(2J' + 1)}{2(2j_3^0 + 1)}} \begin{Bmatrix} J & J' & j_3^0 \\ L' & L & S \end{Bmatrix} (-1)^{1+j_2^0+j_3^0-S+J} \\ \times \delta(j_2^0, L) \delta(j_3^0, \ell) \delta(L'_{12}, L') \delta(S, S') \delta(\ell_3, 0) \delta(\ell'_3, j_3^0) \end{aligned} \quad (\text{B.22})$$

$$\begin{aligned} X_{\ell}(\ell_3 \ell'_3; 1s^2[{}^1S]j_2^0 \text{LSJ}, j_2^0 j_2^0 [L'_{12} S'_{12}] | 1s L' S' J) = \\ = \sqrt{\frac{(2S'_{12} + 1)(2L' + 1)(2J + 1)(2J' + 1)}{(2j_2^0 + 1)}} \begin{Bmatrix} J & J' & j_2^0 \\ L' & L & S \end{Bmatrix} (-1)^{1-S+J} \\ \times \delta(j_2^0, L) \delta(j_2^0, \ell) \delta(L'_{12}, L') \delta(S, S') \delta(\ell_3, 0) \delta(\ell'_3, j_2^0) \end{aligned} \quad (\text{B.23})$$

$$\begin{aligned} Y_{\ell}^{a_1 a_2}(\ell_3 \ell'_3; 1s^2[{}^1S]j_2^0 \text{LSJ}, j_3^0 j_2^0 [L'_{12} S'_{12}] | 1s L' S' J) = \\ = \sqrt{(2S'_{12} + 1)(2a_1 + 1)(2a_2 + 1)(2L' + 1)(2S + 1)(2S' + 1)(2J + 1)(2J' + 1) / 2} \\ \times (-1)^{2a_1 + S' - 1/2 + L + L' - J + J'} \begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \begin{Bmatrix} J & j_3^0 & a_1 \\ L' & S & L \end{Bmatrix} \begin{Bmatrix} a_1 & J & a_2 \\ S' & S & L' \end{Bmatrix} \\ \times \delta(j_2^0, L) \delta(j_3^0, \ell) \delta(L'_{12}, L') \delta(\ell_3, 0) \delta(\ell'_3, j_3^0) \end{aligned} \quad (\text{B.24})$$

$$\begin{aligned}
Y_{\ell}^{a_1 a_2}(\ell_3 \ell'_3; 1s^2 [^1S] j_2^0 \text{LSJ}, j_2^0 j_2^0 [L'_{12} S'_{12}] 1s L' S' J') = \\
= \sqrt{(2S'_{12} + 1)(2a_1 + 1)(2a_2 + 1)(2L' + 1)(2S + 1)(2S' + 1)(2J + 1)(2J' + 1)} \\
\times (-1)^{2a_1 + S' - 1/2 + L + L' - J + J'} \begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \begin{Bmatrix} J & j_2^0 & a_1 \\ L' & S & L \end{Bmatrix} \begin{Bmatrix} a_1 & J' & a_2 \\ S' & S & L' \end{Bmatrix} \\
\times \delta(j_2^0, L) \delta(j_2^0, \ell) \delta(L'_{12}, L') \delta(\ell_3, 0) \delta(\ell'_3, j_2^0)
\end{aligned} \tag{B.25}$$

These formulas allow us to calculate all angular coefficients for our special cases: $(1s^2 [^1S] 2s^2 S - 2p2s [^1,3P] 1s^2 P$ and $1s^2 [^1S] 2l^2 l - 2l^2 [L'_{12} S'_{12}] 1s L' S')$ with $l=0,1$.

Let us consider $1s^2 [^1S] 2s^2 S - 2p2s [^1,3P] 1s^2 P$ excitation. For this special case we obtain from eqs.(B.22), (B.24):

$$\begin{aligned}
X_{\ell}(\ell_3 \ell'_3; 1s^2 [^1S] 2s^2 S_{1/2}, 2p2s [^1S'_{12}] 1s 1S' J') = \\
\sqrt{(2S'_{12} + 1)(2J' + 1)} / 6 (-1)^{J' - 1/2} \delta(\ell, 1) \delta(S', 1/2) \delta(\ell_3, 0) \delta(\ell'_3, 1)
\end{aligned} \tag{B.26}$$

$$\begin{aligned}
Y_{\ell}^{a_1 a_2}(\ell_3 \ell'_3; 1s^2 [^1S] 2s^2 S_{1/2}, 2p2s [^1S'_{12}] 1s 1S' J') = \\
= \sqrt{(2S'_{12} + 1)(2a_1 + 1)(2a_2 + 1)(2S' + 1)(2J' + 1)} \\
\times (-1)^{a_1 + S' + 1/2 + J'} \begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \begin{Bmatrix} a_1 & J' & a_2 \\ S' & 1/2 & 1 \end{Bmatrix} \delta(\ell, 1) \delta(\ell_3, 0) \delta(\ell'_3, 1)
\end{aligned} \tag{B.27}$$

Let us remind (see eq.(B.1)) that we can sum over a_1 and a_2 $(Y)^2$. By using eq.(B.21) we find very simple formula for $(Y)^2$ summed over a_1 and a_2 :

$$\sum_{a_1} \sum_{a_2} \left[Y_{\ell}^{a_1 a_2}(\ell_3 \ell'_3; 1s^2 [^1S] 2s^2 S_{1/2}, 2p2s [^1S'_{12}] 1s 1S' J') \right]^2 = (2J' + 1) \delta(\ell, 1) \delta(\ell_3, 0) \delta(\ell'_3, 1) \tag{B.28}$$

Let us consider $1s^2 [^1S] 2s^2 S_{1/2} - 2s^2 [^1S] 1s^2 S_{1/2}$ excitation. For this special case we obtain from eqs.(B.23), (B.25):

$$X_{\ell}(\ell_3 \ell'_3; 1s^2 [^1S] 2s^2 S_{1/2}, 2s^2 [^1S] 1s^2 S_{1/2}) = \sqrt{2} \delta(\ell, 0) \delta(\ell_3, 0) \delta(\ell'_3, 0) \tag{B.29}$$

$$Y_{\ell}^{a_1 a_2}(\ell_3 \ell'_3; 1s^2 [^1S] 2s^2 S_{1/2}, 2s^2 [^1S] 1s^2 S_{1/2}) = \sqrt{(2a_2 + 1)} \delta(a_1, \frac{1}{2}) \delta(\ell, 0) \delta(\ell_3, 0) \delta(\ell'_3, 0) \tag{B.30}$$

and after sum over a_1 and a_2 we find for $(Y)^2$

$$\sum_{a_1} \sum_{a_2} \left[Y_{\ell}^{a_1 a_2} (\ell_3 \ell'_3; 1s^2 [^1S] 2s^2 S_{1/2}, 2s^2 [^1S] 1s^2 S_{1/2}) \right]^2 = 4\delta(\ell, 0)\delta(\ell_3, 0)\delta(\ell'_3, 0) \quad (\text{B.31})$$

For the third special case $1s^2 [^1S] 2p^2 P_J - 2p^2 [L'_{12} S'_{12}] 1s$ we also can use eqs.(B.23), (B.25):

$$\begin{aligned} X_{\ell} (\ell_3 \ell'_3; 1s^2 [^1S] 2p^2 \frac{1}{2} J, 2p^2 [L'_{12} S'_{12}] 1s L' S' J') &= \delta(\ell, 1)\delta(L'_{12}, L')\delta(S', \frac{1}{2})\delta(\ell_3, 0)\delta(\ell'_3, 1) \\ &\times \sqrt{\frac{(2S'_{12} + 1)(2L' + 1)(2J + 1)(2J' + 1)}{3}} \begin{Bmatrix} J & J' & j_2^0 \\ L' & L & S \end{Bmatrix} (-1)^{1/2+J} \end{aligned} \quad (\text{B.32})$$

$$\begin{aligned} Y_{\ell}^{a_1 a_2} (\ell_3 \ell'_3; 1s^2 [^1S] 2p^2 \frac{1}{2} J, 2p^2 [L'_{12} S'_{12}] 1s L' S' J') &= \delta(\ell, 1)\delta(L'_{12}, L')\delta(\ell_3, 0)\delta(\ell'_3, 1) \\ &= \sqrt{2(2S'_{12} + 1)(2a_1 + 1)(2a_2 + 1)(2L' + 1)(2S' + 1)(2J + 1)(2J' + 1)} \\ &\times (-1)^{2a_1 + 1/2 + L' + S' - J + J'} \begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \begin{Bmatrix} J & 1 & a_1 \\ L' & 1/2 & L \end{Bmatrix} \begin{Bmatrix} a_1 & J' & a_2 \\ S' & 1/2 & L' \end{Bmatrix} \end{aligned} \quad (\text{B.33})$$

Table 1a. Energy of $1s2l2l'$ states counted from $1s^22s$ in unit 10^4 cm^{-1}

Designations: C= $2s2p(^1P)1s$, K= $2s2p(^3P)1s$, S= $1s^22s$

| | C232 | C234 | K232 | K234 | K432 | K434 | K436 |
|----------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Z | -S212 | -S212 | -S212 | -S212 | -S212 | -S212 | -S212 |
| 6 | 244.7552 | 244.7523 | 241.8784 | 241.8880 | 237.3566 | 237.3572 | 237.3670 |
| 7 | 343.0809 | 343.0788 | 339.7243 | 339.7441 | 333.9331 | 333.9369 | 333.9582 |
| 8 | 457.9185 | 457.9195 | 454.0772 | 454.1137 | 447.0132 | 447.0234 | 447.0645 |
| 9 | 589.2845 | 589.2922 | 584.9526 | 585.0144 | 576.6109 | 576.6324 | 576.7044 |
| 10 | 737.1989 | 737.2184 | 732.3687 | 732.4676 | 722.7432 | 722.7825 | 722.9005 |
| 11 | 901.6849 | 901.7230 | 896.3473 | 896.4979 | 885.4298 | 885.4955 | 885.6785 |
| 12 | 1082.769 | 1082.835 | 1076.913 | 1077.133 | 1064.693 | 1064.796 | 1065.068 |
| 13 | 1280.482 | 1280.586 | 1274.092 | 1274.405 | 1260.559 | 1260.711 | 1261.103 |
| 14 | 1494.857 | 1495.013 | 1487.915 | 1488.348 | 1473.054 | 1473.272 | 1473.819 |
| 15 | 1725.932 | 1726.154 | 1718.415 | 1718.999 | 1702.209 | 1702.511 | 1703.257 |
| 16 | 1973.746 | 1974.054 | 1965.625 | 1966.401 | 1948.058 | 1948.464 | 1949.461 |
| 17 | 2238.347 | 2238.759 | 2229.583 | 2230.597 | 2210.636 | 2211.168 | 2212.477 |
| 18 | 2519.782 | 2520.321 | 2510.329 | 2511.638 | 2489.982 | 2490.666 | 2492.357 |
| 19 | 2818.107 | 2818.796 | 2807.905 | 2809.573 | 2786.137 | 2786.999 | 2789.156 |
| 20 | 3133.378 | 3134.242 | 3122.354 | 3124.460 | 3099.145 | 3100.215 | 3102.933 |
| 21 | 3465.660 | 3466.725 | 3453.722 | 3456.357 | 3429.053 | 3430.360 | 3433.749 |
| 22 | 3815.020 | 3816.311 | 3802.058 | 3805.329 | 3775.910 | 3777.486 | 3781.670 |
| 23 | 4181.530 | 4183.073 | 4167.413 | 4171.444 | 4139.770 | 4141.644 | 4146.768 |
| 24 | 4565.268 | 4567.087 | 4549.841 | 4554.775 | 4520.687 | 4522.891 | 4529.116 |
| 25 | 4966.313 | 4968.436 | 4949.398 | 4955.399 | 4918.720 | 4921.283 | 4928.792 |
| 26 | 5384.754 | 5387.202 | 5366.144 | 5373.398 | 5333.932 | 5336.882 | 5345.879 |
| 27 | 5820.680 | 5823.476 | 5800.142 | 5808.861 | 5766.387 | 5769.749 | 5780.464 |
| 28 | 6274.184 | 6277.351 | 6251.458 | 6261.878 | 6216.152 | 6219.948 | 6232.636 |
| 29 | 6745.367 | 6748.923 | 6720.164 | 6732.549 | 6683.301 | 6687.550 | 6702.492 |
| 30 | 7234.329 | 7238.298 | 7206.333 | 7220.975 | 7167.910 | 7172.625 | 7190.131 |
| 31 | 7741.179 | 7745.580 | 7710.046 | 7727.265 | 7670.055 | 7675.249 | 7695.659 |
| 32 | 8266.027 | 8270.880 | 8231.383 | 8251.530 | 8189.820 | 8195.499 | 8219.183 |
| 33 | 8808.990 | 8814.313 | 8770.435 | 8793.890 | 8727.292 | 8733.459 | 8760.818 |
| 34 | 9370.188 | 9376.002 | 9327.290 | 9354.465 | 9282.563 | 9289.215 | 9320.683 |
| 35 | 9949.746 | 9956.068 | 9902.043 | 9933.383 | 9855.727 | 9862.857 | 9898.901 |
| 36 | 10547.79 | 10554.65 | 10494.80 | 10530.78 | 10446.88 | 10454.49 | 10495.60 |
| 37 | 11164.47 | 11171.87 | 11105.66 | 11146.79 | 11056.13 | 11064.20 | 11110.92 |
| 38 | 11799.91 | 11807.88 | 11734.74 | 11781.56 | 11683.59 | 11692.10 | 11745.00 |
| 39 | 12454.26 | 12462.82 | 12382.14 | 12435.23 | 12329.37 | 12338.30 | 12397.97 |
| 40 | 13127.68 | 13136.85 | 13048.00 | 13107.96 | 12993.58 | 13002.92 | 13070.01 |
| 41 | 13820.32 | 13830.12 | 13732.43 | 13799.91 | 13676.35 | 13686.08 | 13761.25 |
| 42 | 14532.35 | 14542.79 | 14435.56 | 14511.25 | 14377.81 | 14387.90 | 14471.87 |

Table 1b. Energy of $1s^2 2l^2$ states counted from $1s^2 2s$ in unit 10^4 cm^{-1}

Designations: E= $2s^2(^1S)1s$, M= $2p^2(^3P)1s$, F= $2p^2(^1S)1s$, F= $2p^2(^1D)1s$, S= $1s^2 2s$

| Z | E212 | M432 | M232 | F212 | M434 | M234 | F254 | M436 | F256 |
|----|----------|----------|----------|----------|----------|----------|----------|----------|-----------|
| | -S212 | -S212 | -S212 | -S212 | -S212 | -S212 | -S212 | -S212 | -S212- |
| 6 | 235.1398 | 244.9464 | 248.1032 | 252.4275 | 244.9540 | 248.1180 | 247.3929 | 244.9577 | 247.3765 |
| 7 | 331.3839 | 343.0646 | 347.3383 | 352.4494 | 343.0805 | 347.3694 | 346.3627 | 343.0914 | 346.3360 |
| 8 | 444.1281 | 457.7006 | 463.0894 | 468.9961 | 457.7301 | 463.1476 | 461.8588 | 457.7544 | 461.8188 |
| 9 | 573.3867 | 588.8725 | 595.3748 | 602.0880 | 588.9229 | 595.4755 | 593.9023 | 588.9695 | 593.8459 |
| 10 | 719.1762 | 736.6019 | 744.2162 | 751.7502 | 736.6831 | 744.3801 | 742.5181 | 736.7639 | 742.4425 |
| 11 | 881.5165 | 900.9139 | 909.6391 | 918.0115 | 901.0382 | 909.8934 | 907.7348 | 901.1685 | 907.6382 |
| 12 | 1060.430 | 1081.836 | 1091.672 | 1100.906 | 1082.020 | 1092.052 | 1089.584 | 1082.218 | 1089.4670 |
| 13 | 1255.940 | 1279.401 | 1290.346 | 1300.470 | 1279.662 | 1290.897 | 1288.100 | 1279.952 | 1287.9650 |
| 14 | 1468.076 | 1493.640 | 1505.697 | 1516.748 | 1494.004 | 1506.474 | 1503.322 | 1494.412 | 1503.1760 |
| 15 | 1696.866 | 1724.592 | 1737.763 | 1749.786 | 1725.087 | 1738.836 | 1735.290 | 1725.645 | 1735.1470 |
| 16 | 1942.344 | 1972.296 | 1986.584 | 1999.637 | 1972.957 | 1988.038 | 1984.048 | 1973.699 | 1983.9270 |
| 17 | 2204.544 | 2236.793 | 2252.205 | 2266.358 | 2237.662 | 2254.143 | 2249.642 | 2238.626 | 2249.5740 |
| 18 | 2483.504 | 2518.128 | 2534.673 | 2550.012 | 2519.255 | 2537.217 | 2532.123 | 2520.482 | 2532.1500 |
| 19 | 2779.264 | 2816.347 | 2834.040 | 2850.668 | 2817.791 | 2837.332 | 2831.544 | 2819.324 | 2831.7210 |
| 20 | 3091.868 | 3131.499 | 3150.359 | 3168.399 | 3133.330 | 3154.564 | 3147.962 | 3135.213 | 3148.3620 |
| 21 | 3421.359 | 3463.633 | 3483.692 | 3503.288 | 3465.937 | 3488.996 | 3481.438 | 3468.210 | 3482.1500 |
| 22 | 3767.788 | 3812.800 | 3834.099 | 3855.417 | 3815.676 | 3840.713 | 3832.037 | 3818.380 | 3833.1740 |
| 23 | 4131.204 | 4179.054 | 4201.649 | 4224.880 | 4182.619 | 4209.805 | 4199.830 | 4185.789 | 4201.5250 |
| 24 | 4511.661 | 4562.449 | 4586.417 | 4611.774 | 4566.841 | 4596.368 | 4584.889 | 4570.506 | 4587.3050 |
| 25 | 4909.215 | 4963.041 | 4988.480 | 5016.201 | 4968.421 | 5000.501 | 4987.293 | 4972.602 | 4990.6170 |
| 26 | 5323.927 | 5380.885 | 5407.925 | 5438.270 | 5387.440 | 5422.310 | 5407.125 | 5392.150 | 5411.5770 |
| 27 | 5755.857 | 5816.041 | 5844.841 | 5878.093 | 5823.986 | 5861.904 | 5844.473 | 5829.229 | 5850.3000 |
| 28 | 6205.071 | 6268.568 | 6299.326 | 6335.789 | 6278.150 | 6319.397 | 6299.426 | 6283.920 | 6306.9100 |
| 29 | 6671.639 | 6738.529 | 6771.482 | 6811.481 | 6750.028 | 6794.910 | 6772.082 | 6756.313 | 6781.5330 |
| 30 | 7155.629 | 7225.991 | 7261.417 | 7305.299 | 7239.720 | 7288.568 | 7262.543 | 7246.500 | 7274.3020 |
| 31 | 7657.120 | 7731.023 | 7769.244 | 7817.376 | 7747.331 | 7800.501 | 7770.912 | 7754.581 | 7785.3510 |
| 32 | 8176.187 | 8253.699 | 8295.078 | 8347.853 | 8272.968 | 8330.846 | 8297.300 | 8280.662 | 8314.8180 |
| 33 | 8712.912 | 8794.099 | 8839.043 | 8896.872 | 8816.747 | 8879.744 | 8841.821 | 8824.855 | 8862.8510 |
| 34 | 9267.381 | 9352.306 | 9401.261 | 9464.585 | 9378.787 | 9447.342 | 9404.598 | 9387.278 | 9429.5920 |
| 35 | 9839.682 | 9928.411 | 9981.863 | 10051.15 | 9959.214 | 10033.79 | 9985.753 | 9968.054 | 10015.200 |
| 36 | 10429.91 | 10522.51 | 10580.98 | 10656.72 | 10558.16 | 10639.26 | 10585.42 | 10567.32 | 10619.83 |
| 37 | 11038.16 | 11134.70 | 11198.75 | 11281.47 | 11175.75 | 11263.90 | 11203.73 | 11185.20 | 11243.65 |
| 38 | 11664.53 | 11765.10 | 11835.32 | 11925.57 | 11812.13 | 11907.90 | 11840.82 | 11821.84 | 11886.83 |
| 39 | 12309.12 | 12413.81 | 12490.83 | 12589.20 | 12467.45 | 12571.42 | 12496.85 | 12477.38 | 12549.54 |
| 40 | 12972.05 | 13080.95 | 13165.44 | 13272.55 | 13141.85 | 13254.66 | 13171.96 | 13151.99 | 13231.97 |
| 41 | 13653.43 | 13766.65 | 13859.30 | 13975.82 | 13835.51 | 13957.80 | 13866.32 | 13934.32 | 13845.82 |
| 42 | 14353.37 | 14471.04 | 14572.57 | 14699.19 | 14548.57 | 14681.05 | 14580.08 | 14656.78 | 14559.03 |

Table 1c. The 1s energy obtained as a difference between the energies of $1s^2 2s^2 S_{1/2}$ and $1s2s^3 S_1$ levels

| Z=6 | Z=7 | Z=8 | Z=10 | Z=12 | Z=13 | Z=14 | Z=16 | Z=20 |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 293.1477 | 417.5412 | 563.9389 | 922.8301 | 1370.026 | 1626.819 | 1905.792 | 2530.453 | 4048.059 |
| Z=22 | Z=26 | Z=28 | Z=30 | Z=32 | Z=34 | Z=36 | Z=42 | |
| 4941.96 | 7002.83 | 8171.15 | 9432.41 | 10787.47 | 12237.26 | 13782.78 | 19005.27 | |

Table 1d. The 2p, 2s energies obtained as a difference between the energies of $1s2s2p$ (LSJ) and $1s2s^3 S_1$ levels, $1s2s^2 (^2S_{1/2})$ and $1s2s (^3S_1)$ levels.

| Level | Z=6 | Z=7 | Z=8 | Z=10 | Z=12 | Z=13 | Z=14 | Z=16 | Z=20 |
|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| K234 | 51.257 | 77.798 | 109.827 | 190.337 | 292.896 | 352.419 | 417.452 | 564.043 | 923.649 |
| K232 | 51.269 | 77.821 | 109.869 | 190.444 | 293.116 | 352.719 | 417.872 | 564.813 | 925.689 |
| C234 | 48.398 | 74.464 | 106.022 | 185.639 | 287.186 | 346.229 | 410.782 | 556.393 | 913.849 |
| C232 | 48.392 | 74.464 | 106.022 | 185.639 | 287.256 | 346.339 | 410.782 | 556.703 | 914.639 |
| K434 | 55.793 | 83.607 | 116.912 | 200.026 | 305.236 | 366.099 | 432.522 | 581.973 | 947.859 |
| K432 | 55.793 | 83.607 | 116.932 | 200.078 | 305.336 | 366.259 | 434.902 | 582.393 | 948.919 |
| E212 | 58.009 | 86.152 | 119.810 | 203.664 | 309.536 | 370.889 | 437.712 | 588.103 | 956.199 |
| F212 | 40.718 | 65.093 | 94.940 | 171.003 | 269.116 | 326.349 | 389.052 | 530.813 | 879.689 |
| M232 | 45.046 | 70.186 | 100.847 | 178.616 | 278.356 | 336.479 | 400.082 | 543.883 | 897.989 |
| M432 | 48.200 | 74.476 | 106.231 | 186.236 | 288.186 | 347.429 | 412.162 | 558.143 | 916.599 |
| Level | Z=22 | Z=26 | Z=28 | Z=30 | Z=32 | Z=34 | Z=36 | Z=42 | |
| K234 | 1136.96 | 1629.37 | 1909.41 | 2211.67 | 2535.96 | 2882.72 | 3252.08 | 4493.97 | |
| K232 | 1139.97 | 1636.58 | 1919.59 | 2226.24 | 2556.34 | 2909.77 | 3287.98 | 4569.67 | |
| C234 | 1125.60 | 1615.77 | 1893.69 | 2193.90 | 2516.86 | 2861.67 | 3228.18 | 4462.57 | |
| C232 | 1126.91 | 1618.09 | 1896.84 | 2198.09 | 2521.64 | 2866.95 | 3235.08 | 4472.97 | |
| K434 | 1164.53 | 1666.08 | 1951.08 | 2259.84 | 2592.09 | 2947.90 | 3328.28 | 4617.37 | |
| K432 | 1166.10 | 1668.93 | 1954.95 | 2264.47 | 2597.47 | 2954.79 | 3335.88 | 4534.37 | |
| E212 | 1174.20 | 1678.87 | 1966.14 | 2276.77 | 2611.52 | 2970.28 | 3362.88 | 4627.57 | |
| F212 | 1086.61 | 1564.50 | 1835.22 | 2127.27 | 2439.53 | 2772.94 | 3126.18 | 4306.07 | |
| M232 | 1107.90 | 1594.79 | 1871.94 | 2170.77 | 2492.16 | 2836.11 | 3201.78 | 4432.67 | |
| M432 | 1129.10 | 1621.86 | 1902.74 | 2206.45 | 2533.92 | 2885.35 | 3260.28 | 4651.87 | |

**Table 2. Comparison N'_l and N''_l with A'_l and A''_l obtained for $Z=26$
a) 1s-2p excitation**

| Transitions | N'_l | A'_l | N''_l | A''_l |
|--|--------|--------|---------|---------|
| $1s^2 [^1S]2s^2 S_{1/2}-2p2s(^1P)1s^2 P_{1/2}$ S212 -C232 | 0.167 | 0.232 | 0.167 | 0.167 |
| $1s^2 [^1S]2s^2 S_{1/2}-2p2s(^3P)1s^2 P_{1/2}$ S212 -K232 | 0.5 | 0.426 | 0.167 | 0.167 |
| $1s^2 [^1S]2s^2 S_{1/2}-2p2s(^3P)1s^4 P_{1/2}$ S212 -K432 | 0 | 0.007 | 0.167 | 0.167 |
| $1s^2 [^1S]2s^2 S_{1/2}-2p2s(^1P)1s^2 P_{3/2}$ S212 -C234 | 0.333 | 0.002 | 0.333 | 0.333 |
| $1s^2 [^1S]2s^2 S_{1/2}-2p2s(^3P)1s^2 P_{3/2}$ S212 -K234 | 1.0 | 1.29 | 0.333 | 0.333 |
| $1s^2 [^1S]2s^2 S_{1/2}-2p2s(^3P)1s^4 P_{3/2}$ S212 -K434 | 0 | 0.043 | 0.333 | 0.333 |
| $1s^2 [^1S]2s^2 S_{1/2}-2p2s(^3P)1s^4 P_{5/2}$ S212 -K436 | 0 | 0 | 0.5 | 0.5 |

b) 1s-2s excitation

| Transitions | N'_l | A'_l | N''_l | A''_l |
|--|--------|--------|---------|---------|
| $1s^2 [^1S]2s^2 S_{1/2}-2s^2(^1S)1s^2 S_{1/2}$ S212 -E212 | 1.0 | 0.923 | 1.0 | 0.923 |
| $1s^2 [^1S]2s^2 S_{1/2}-2p^2(^3P)1s^2 P_{1/2}$ S212 -M232 | 0 | 0.0048 | 0 | 0.0048 |
| $1s^2 [^1S]2s^2 S_{1/2}-2p^2(^1S)1s^2 S_{1/2}$ S212 -F212 | 0 | 0.0610 | 0 | 0.0610 |
| $1s^2 [^1S]2s^2 S_{1/2}-2p^2(^3P)1s^4 P_{1/2}$ S212 -M432 | 0 | 0.0110 | 0 | 0.0110 |

Table 2 (continued) c)1s-2p excitation

| Transitions | N'_l | A'_l | N''_l | A''_l |
|---|--------|--------|---------|---------|
| $1s^2 [^1S]2p \ ^2P_{3/2} - 2p^2(^3P)1s \ ^2P_{3/2}$ P234 -M234 | 0.823 | 0.0230 | 0.259 | 0.322 |
| $1s^2 [^1S]2p \ ^2P_{3/2} - 2p^2(^1D)1s \ ^2D_{3/2}$ P234 -F254 | 0.0555 | 0.0524 | 0.222 | 0.171 |
| $1s^2 [^1S]2p \ ^2P_{3/2} - 2p^2(^3P)1s \ ^4P_{3/2}$ P234 -M434 | 0 | 0.137 | 0.185 | 0.174 |
| $1s^2 [^1S]2p \ ^2P_{3/2} - 2p^2(^1D)1s \ ^2D_{5/2}$ P234 -F256 | 0.5 | 0.429 | 0.333 | 0.427 |
| $1s^2 [^1S]2p \ ^2P_{3/2} - 2p^2(^3P)1s \ ^4P_{5/2}$ P234 -M436 | 0 | 0.0707 | 0.417 | 0.323 |
| $1s^2 [^1S]2p \ ^2P_{1/2} - 2p^2(^1D)1s \ ^2D_{5/2}$ P232 -F256 | 0 | 0 | 0.167 | 0.146 |
| $1s^2 [^1S]2p \ ^2P_{1/2} - 2p^2(^3P)1s \ ^4P_{5/2}$ P232 -M436 | 0 | 0 | 0.333 | 0.354 |

Table 2 (continued) c)1s-2p excitation

| Transitions | N'_l | A'_l | N''_l | A''_l |
|---|--------|----------------------|---------|---------|
| $1s^2 [^1S]2p \ ^2P_{1/2} - 2p^2(^3P)1s \ ^2P_{1/2}$ P232 -M232 | 0.667 | 0.722 | 0.185 | 0.198 |
| $1s^2 [^1S]2p \ ^2P_{1/2} - 2p^2(^1S)1s \ ^2S_{1/2}$ P232 -F212 | 0.111 | 0.0148 | 0.111 | 0.0335 |
| $1s^2 [^1S]2p \ ^2P_{1/2} - 2p^2(^3P)1s \ ^4P_{1/2}$ P232 -M432 | 0 | 0.0284 | 0.204 | 0.255 |
| $1s^2 [^1S]2p \ ^2P_{1/2} - 2s^2(^1S)1s \ ^2S_{1/2}$ P232 -E212 | 0 | 0.0123 | 0 | 0.0135 |
| $1s^2 [^1S]2p \ ^2P_{3/2} - 2p^2(^3P)1s \ ^2P_{1/2}$ P234 -M232 | 0.167 | 0.110 | 0.0741 | 0.0669 |
| $1s^2 [^1S]2p \ ^2P_{3/2} - 2p^2(^1S)1s \ ^2S_{1/2}$ P234 -F212 | 0.111 | 0.162 | 0.111 | 0.140 |
| $1s^2 [^1S]2p \ ^2P_{3/2} - 2p^2(^3P)1s \ ^4P_{1/2}$ P234 -M432 | 0 | 7.0×10^{-5} | 0.0648 | 0.0373 |
| $1s^2 [^1S]2p \ ^2P_{3/2} - 2s^2(^1S)1s \ ^2S_{1/2}$ P234 -E212 | 0 | 0.006 | 0 | 0.006 |
| $1s^2 [^1S]2p \ ^2P_{1/2} - 2p^2(^3P)1s \ ^2P_{3/2}$ P232 -M234 | 0.333 | 0.0230 | 0.148 | 0.0223 |
| $1s^2 [^1S]2p \ ^2P_{1/2} - 2p^2(^1D)1s \ ^2D_{3/2}$ P232 -F254 | 0.555 | 0.866 | 0.222 | 0.325 |
| $1s^2 [^1S]2p \ ^2P_{1/2} - 2p^2(^3P)1s \ ^4P_{3/2}$ P232 -M434 | 0 | 5.7×10^{-5} | 0.296 | 0.319 |

Table 3. Wavelengths (WL) in Å, radiative transition probabilities (Ar), autoionization rates (Γ), relative factor intensities (Qd) in $10^{13}s^{-1}$, branching ratio (K), angular coefficients for cross section of excitation (A' and A''). Designations: C=2s2p(¹P)1s, K=2s2p(³P)1s, S=1s²2s,

a) 1s-2p excitation

| Z=6 Transition | | WL | Ar | Γ | K | Qd | A' | A'' |
|------------------------|-----------|-----------|-----------|----------|----------|-----------|-----------|------------|
| t | C232-S212 | 40.875 | 7.99-03 | 1.17+01 | 6.85-04 | 1.60-02 | 6.11-02 | 1.67-01 |
| s | C234-S212 | 40.876 | 7.70-03 | 1.17+01 | 6.58-04 | 3.08-02 | 1.10-01 | 3.33-01 |
| q | K234-S212 | 41.360 | 7.18-02 | 4.82-01 | 1.30-01 | 2.50-01 | 1.22+00 | 3.33-01 |
| r | K232-S212 | 41.361 | 7.15-02 | 5.11-01 | 1.23-01 | 1.25-01 | 6.06-01 | 1.67-01 |
| u | K434-S212 | 42.150 | 4.63-07 | 5.64-06 | 7.57-02 | 1.71-06 | 8.22-06 | 3.33-01 |
| v | K432-S212 | 42.150 | 1.75-07 | 9.16-09 | 9.01-01 | 1.65-08 | 1.56-06 | 1.67-01 |
| Z=7 Transition | | WL | Ar | Γ | K | Qd | A' | A'' |
| t | C232-S212 | 29.155 | 1.66-02 | 1.16+01 | 1.42-03 | 3.31-02 | 6.23-02 | 1.67-01 |
| s | C234-S212 | 29.156 | 1.55-02 | 1.17+01 | 1.33-03 | 6.21-02 | 1.17-01 | 3.33-01 |
| q | K234-S212 | 29.442 | 1.49-01 | 4.75-01 | 2.39-01 | 4.53-01 | 1.22+00 | 3.33-01 |
| r | K232-S212 | 29.444 | 1.48-01 | 5.26-01 | 2.19-01 | 2.31-01 | 6.04-01 | 1.67-01 |
| u | K434-S212 | 29.954 | 2.39-06 | 1.71-05 | 1.23-01 | 8.39-06 | 2.04-05 | 3.33-01 |
| v | K432-S212 | 29.954 | 9.13-07 | 4.12-07 | 6.84-01 | 5.63-07 | 3.91-06 | 1.67-01 |
| Z=8 Transition | | WL | Ar | Γ | K | Qd | A' | A'' |
| s | C234-S212 | 21.842 | 2.80-02 | 1.17+01 | 2.38-03 | 1.12-01 | 1.14-01 | 3.33-01 |
| t | C232-S212 | 21.842 | 3.10-02 | 1.16+01 | 2.66-03 | 6.18-02 | 6.36-02 | 1.67-01 |
| q | K234-S212 | 22.025 | 2.76-01 | 4.62-01 | 3.74-01 | 6.91-01 | 1.22+00 | 3.33-01 |
| r | K232-S212 | 22.027 | 2.73-01 | 5.43-01 | 3.35-01 | 3.63-01 | 6.03-01 | 1.67-01 |
| u | K434-S212 | 22.374 | 9.85-06 | 4.36-05 | 1.84-01 | 3.21-05 | 4.52-05 | 3.33-01 |
| v | K432-S212 | 22.375 | 3.77-06 | 2.31-06 | 6.19-01 | 2.86-06 | 8.69-06 | 1.67-01 |
| Z=10 Transition | | WL | Ar | Γ | K | Qd | A' | A'' |
| s | C234-S212 | 13.566 | 7.08-02 | 1.18+01 | 5.99-03 | 2.82-01 | 1.08-01 | 3.33-01 |
| t | C232-S212 | 13.566 | 8.84-02 | 1.16+01 | 7.57-03 | 1.75-01 | 6.75-02 | 1.67-01 |
| q | K234-S212 | 13.654 | 7.59-01 | 4.20-01 | 6.44-01 | 1.08+00 | 1.23+00 | 3.33-01 |
| r | K232-S212 | 13.656 | 7.42-01 | 5.93-01 | 5.56-01 | 6.59-01 | 5.99-01 | 1.67-01 |
| u | K434-S212 | 13.837 | 1.03-04 | 2.00-04 | 3.40-01 | 2.71-04 | 1.72-04 | 3.33-01 |
| v | K432-S212 | 13.837 | 3.95-05 | 2.06-05 | 6.57-01 | 2.70-05 | 3.30-05 | 1.67-01 |

Table 3 (continued) a) 1s-2p excitation

| Z=12 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------------------------|----------|-----------|-----------|------------|
| s | C234-S212 | 9.2355 | 1.42-01 | 1.18+01 | 1.19-02 | 5.62-01 | 9.76-02 | 3.33-01 |
| t | C232-S212 | 9.2360 | 2.13-01 | 1.15+01 | 1.82-02 | 4.18-01 | 7.36-02 | 1.67-01 |
| q | K234-S212 | 9.2844 | 1.71+00 | 3.60-01 | 8.26-01 | 1.19+00 | 1.24+00 | 3.33-01 |
| r | K232-S212 | 9.2863 | 1.64+00 | 6.74-01 | 7.09-01 | 9.55-01 | 5.93-01 | 1.67-01 |
| u | K434-S212 | 9.3919 | 6.86-04 | 6.72-04 | 5.05-01 | 1.36-03 | 5.10-04 | 3.33-01 |
| v | K432-S212 | 9.3929 | 2.62-04 | 9.20-05 | 7.40-01 | 1.36-04 | 9.75-05 | 1.67-01 |
| Z=13 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
| s | C234-S212 | 7.8092 | 1.88-01 | 1.19+01 | 1.56-02 | 7.40-01 | 9.13-02 | 3.33-01 |
| t | C232-S212 | 7.8099 | 3.18-01 | 1.14+01 | 2.70-02 | 6.19-01 | 7.78-02 | 1.67-01 |
| q | K234-S212 | 7.8471 | 2.43+00 | 3.24-01 | 8.83-01 | 1.14+00 | 1.24+00 | 3.33-01 |
| r | K232-S212 | 7.8490 | 2.31+00 | 7.31-01 | 7.59-01 | 1.11+00 | 5.89-01 | 1.67-01 |
| u | K434-S212 | 7.9323 | 1.57-03 | 1.14-03 | 5.80-01 | 2.64-03 | 8.23-04 | 3.33-01 |
| v | K432-S212 | 7.9333 | 5.95-04 | 1.69-04 | 7.79-01 | 2.63-04 | 1.56-04 | 1.67-01 |
| Z=14 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
| s | C234-S212 | 6.6891 | 2.39-01 | 1.19+01 | 1.97-02 | 9.37-01 | 8.44-02 | 3.33-01 |
| t | C232-S212 | 6.6898 | 4.65-01 | 1.14+01 | 3.93-02 | 8.94-01 | 8.30-02 | 1.67-01 |
| q | K234-S212 | 6.7191 | 3.37+00 | 2.85-01 | 9.22-01 | 1.05+00 | 1.25+00 | 3.33-01 |
| r | K232-S212 | 6.7210 | 3.15+00 | 8.01-01 | 7.97-01 | 1.28+00 | 5.83-01 | 1.67-01 |
| u | K434-S212 | 6.7878 | 3.37-03 | 1.84-03 | 6.46-01 | 4.77-03 | 1.28-03 | 3.33-01 |
| v | K432-S212 | 6.7888 | 1.27-03 | 2.90-04 | 8.14-01 | 4.72-04 | 2.41-04 | 1.67-01 |
| Z=16 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
| s | C234-S212 | 5.0658 | 3.45-01 | 1.20+01 | 2.80-02 | 1.34+00 | 6.88-02 | 3.33-01 |
| t | C232-S212 | 5.0666 | 9.55-01 | 1.12+01 | 7.87-02 | 1.76+00 | 9.65-02 | 1.67-01 |
| q | K234-S212 | 5.0855 | 6.06+00 | 2.01-01 | 9.68-01 | 7.79-01 | 1.26+00 | 3.33-01 |
| r | K232-S212 | 5.0875 | 5.46+00 | 9.90-01 | 8.46-01 | 1.68+00 | 5.70-01 | 1.67-01 |
| u | K434-S212 | 5.1324 | 1.32-02 | 4.38-03 | 7.51-01 | 1.32-02 | 2.82-03 | 3.33-01 |
| v | K432-S212 | 5.1334 | 4.87-03 | 7.31-04 | 8.69-01 | 1.27-03 | 5.19-04 | 1.67-01 |
| Z=20 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
| s | C234-S212 | 3.1906 | 4.56-01 | 1.21+01 | 3.63-02 | 1.76+00 | 3.51-02 | 3.33-01 |
| t | C232-S212 | 3.1915 | 3.52+00 | 1.06+01 | 2.50-01 | 5.28+00 | 1.39-01 | 1.67-01 |
| q | K234-S212 | 3.2006 | 1.60+01 | 5.15-02 | 9.97-01 | 2.06-01 | 1.29+00 | 3.33-01 |
| r | K232-S212 | 3.2027 | 1.30+01 | 1.62+00 | 8.89-01 | 2.88+00 | 5.26-01 | 1.67-01 |
| u | K434-S212 | 3.2256 | 1.26-01 | 1.81-02 | 8.74-01 | 6.33-02 | 1.03-02 | 3.33-01 |
| v | K432-S212 | 3.2267 | 4.35-02 | 2.98-03 | 9.36-01 | 5.58-03 | 1.79-03 | 1.67-01 |

Table 3 (continued) 1s-2p excitation

| Z=22 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------------------------|----------|-----------|-----------|------------|
| s | C234-S212 | 2.6204 | 3.94-01 | 1.21+01 | 3.14-02 | 1.52+00 | 2.01-02 | 3.33-01 |
| t | C232-S212 | 2.6212 | 6.35+00 | 1.01+01 | 3.86-01 | 7.79+00 | 1.67-01 | 1.67-01 |
| q | K234-S212 | 2.6279 | 2.42+01 | 9.41-03 | 1.00+00 | 3.76-02 | 1.30+00 | 3.33-01 |
| r | K232-S212 | 2.6302 | 1.84+01 | 2.08+00 | 8.99-01 | 3.74+00 | 4.96-01 | 1.67-01 |
| u | K434-S212 | 2.6473 | 3.23-01 | 3.27-02 | 9.08-01 | 1.19-01 | 1.77-02 | 3.33-01 |
| v | K432-S212 | 2.6484 | 1.07-01 | 5.12-03 | 9.55-01 | 9.77-03 | 2.93-03 | 1.67-01 |
| Z=26 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
| s | C234-S212 | 1.8563 | 7.78-02 | 1.21+01 | 6.41-03 | 3.09-01 | 1.83-03 | 3.33-01 |
| t | C232-S212 | 1.8571 | 1.79+01 | 8.96+00 | 6.67-01 | 1.19+01 | 2.34-01 | 1.67-01 |
| q | K234-S212 | 1.8610 | 4.87+01 | 3.02-02 | 9.99-01 | 1.21-01 | 1.29+00 | 3.33-01 |
| r | K232-S212 | 1.8635 | 3.19+01 | 3.21+00 | 9.09-01 | 5.83+00 | 4.26-01 | 1.67-01 |
| u | K434-S212 | 1.8738 | 1.59+00 | 8.85-02 | 9.47-01 | 3.35-01 | 4.30-02 | 3.33-01 |
| v | K432-S212 | 1.8748 | 4.92-01 | 1.19-02 | 9.76-01 | 2.32-02 | 6.65-03 | 1.67-01 |
| Z=28 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
| s | C234-S212 | 1.5930 | 1.09-03 | 1.20+01 | 9.16-05 | 4.38-03 | 4.70-05 | 3.33-01 |
| t | C232-S212 | 1.5938 | 2.79+01 | 8.35+00 | 7.70-01 | 1.29+01 | 2.67-01 | 1.67-01 |
| q | K234-S212 | 1.5970 | 6.56+01 | 9.10-02 | 9.99-01 | 3.64-01 | 1.27+00 | 3.33-01 |
| r | K232-S212 | 1.5996 | 3.99+01 | 3.81+00 | 9.13-01 | 6.95+00 | 3.90-01 | 1.67-01 |
| u | K434-S212 | 1.6077 | 3.13+00 | 1.34-01 | 9.59-01 | 5.13-01 | 6.18-02 | 3.33-01 |
| v | K432-S212 | 1.6087 | 9.35-01 | 1.65-02 | 9.83-01 | 3.24-02 | 9.15-03 | 1.67-01 |
| Z=30 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
| s | C234-S212 | 1.3815 | 1.89-01 | 1.18+01 | 1.57-02 | 7.43-01 | 2.94-03 | 3.33-01 |
| t | C232-S212 | 1.3823 | 4.16+01 | 7.77+00 | 8.42-01 | 1.31+01 | 2.99-01 | 1.67-01 |
| q | K234-S212 | 1.3849 | 8.61+01 | 1.74-01 | 9.98-01 | 6.96-01 | 1.25+00 | 3.33-01 |
| r | K232-S212 | 1.3877 | 4.88+01 | 4.38+00 | 9.18-01 | 8.04+00 | 3.56-01 | 1.67-01 |
| u | K434-S212 | 1.3942 | 5.73+00 | 1.92-01 | 9.67-01 | 7.45-01 | 8.45-02 | 3.33-01 |
| v | K432-S212 | 1.3951 | 1.67+00 | 2.16-02 | 9.87-01 | 4.26-02 | 1.23-02 | 1.67-01 |
| Z=32 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
| s | C234-S212 | 1.2091 | 8.44-01 | 1.16+01 | 6.76-02 | 3.15+00 | 9.62-03 | 3.33-01 |
| t | C232-S212 | 1.2098 | 5.94+01 | 7.24+00 | 8.91-01 | 1.29+01 | 3.24-01 | 1.67-01 |
| q | K234-S212 | 1.2119 | 1.10+02 | 2.69-01 | 9.98-01 | 1.07+00 | 1.21+00 | 3.33-01 |
| r | K232-S212 | 1.2149 | 5.86+01 | 4.91+00 | 9.23-01 | 9.05+00 | 3.26-01 | 1.67-01 |
| u | K434-S212 | 1.2202 | 9.82+00 | 2.64-01 | 9.74-01 | 1.03+00 | 1.10-01 | 3.33-01 |
| v | K432-S212 | 1.2210 | 2.81+00 | 2.70-02 | 9.90-01 | 5.35-02 | 1.58-02 | 1.67-01 |

Table 3 (continued) a) 1s-2p excitation

| Z=34 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------|----------|-----------|-----------|------------|
| s | C234-S212 | 1.0666 | 2.18+00 | 1.15+01 | 1.60-01 | 7.34+00 | 1.90-02 | 3.33-01 |
| t | C232-S212 | 1.0672 | 8.19+01 | 6.78+00 | 9.24-01 | 1.25+01 | 3.47-01 | 1.67-01 |
| q | K234-S212 | 1.0690 | 1.38+02 | 3.65-01 | 9.97-01 | 1.46+00 | 1.18+00 | 3.33-01 |
| r | K232-S212 | 1.0721 | 6.96+01 | 5.37+00 | 9.28-01 | 9.96+00 | 3.00-01 | 1.67-01 |
| u | K434-S212 | 1.0765 | 1.59+01 | 3.46-01 | 9.79-01 | 1.35+00 | 1.38-01 | 3.33-01 |
| v | K432-S212 | 1.0773 | 4.50+00 | 3.24-02 | 9.93-01 | 6.43-02 | 1.96-02 | 1.67-01 |

| Z=36 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------|----------|-----------|-----------|------------|
| s | C234-S212 | .94745 | 4.43+00 | 1.13+01 | 2.82-01 | 1.27+01 | 3.01-02 | 3.33-01 |
| t | C232-S212 | .94807 | 1.10+02 | 6.38+00 | 9.45-01 | 1.21+01 | 3.65-01 | 1.67-01 |
| q | K234-S212 | .94960 | 1.70+02 | 4.56-01 | 9.97-01 | 1.82+00 | 1.14+00 | 3.33-01 |
| r | K232-S212 | .95285 | 8.20+01 | 5.76+00 | 9.34-01 | 1.08+01 | 2.78-01 | 1.67-01 |
| u | K434-S212 | .95653 | 2.44+01 | 4.36-01 | 9.82-01 | 1.71+00 | 1.67-01 | 3.33-01 |
| v | K432-S212 | .95722 | 6.90+00 | 3.75-02 | 9.95-01 | 7.45-02 | 2.36-02 | 1.67-01 |

| Z=42 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------|----------|-----------|-----------|------------|
| s | C234-S212 | .68763 | 1.88+01 | 1.08+01 | 6.36-01 | 2.74+01 | 6.57-02 | 3.33-01 |
| t | C232-S212 | .68812 | 2.32+02 | 5.50+00 | 9.77-01 | 1.07+01 | 4.00-01 | 1.67-01 |
| q | K234-S212 | .68912 | 2.94+02 | 6.72-01 | 9.98-01 | 2.68+00 | 1.02+00 | 3.33-01 |
| r | K232-S212 | .69273 | 1.30+02 | 6.63+00 | 9.52-01 | 1.26+01 | 2.31-01 | 1.67-01 |
| u | K434-S212 | .69503 | 6.92+01 | 7.20-01 | 9.90-01 | 2.85+00 | 2.47-01 | 3.33-01 |
| v | K432-S212 | .69552 | 2.03+01 | 4.87-02 | 9.98-01 | 9.72-02 | 3.62-02 | 1.67-01 |

Table 3. Wavelengths (WL) in Å, radiative transition probabilities (Ar), autoionization rates (Γ), relative factor intensities (Qd) in 10^{13} s^{-1} , branching ratio (K), angular coefficients for cross section of excitation (A' and A'').

Designations: E=2s²(¹S)1s, M=2p²(³P)1s, F=2p²(¹S)1s, F=2p²(¹D)1s, S=1s²2s, P=1s²2p

b) 1s-2s excitation

| Z=6 Transition | | WL | Ar | Γ | K | Qd | A' | A'' |
|-----------------------|-----------|-----------|-----------|----------------------------|----------|-----------|-----------|------------|
| n | F212-P232 | 40.710 | 1.13-02 | 2.30+00 | 4.85-03 | 2.23-02 | 5.64-04 | 5.64-04 |
| m | F212-P234 | 40.712 | 2.31-02 | 2.30+00 | 9.90-03 | 4.55-02 | 1.18-03 | 1.18-03 |
| d | M232-P232 | 41.439 | 7.90-02 | 8.24-06 | 6.68-01 | 1.10-05 | 8.42-07 | 8.42-07 |
| c | M232-P234 | 41.441 | 3.93-02 | 8.24-06 | 3.32-01 | 5.47-06 | 4.18-07 | 4.18-07 |
| i | M432-P232 | 41.989 | 3.14-07 | 1.65-06 | 1.59-01 | 5.25-07 | 2.18-07 | 2.18-07 |
| h | M432-P234 | 41.991 | 4.49-10 | 1.65-06 | 2.27-04 | 7.51-10 | 3.11-10 | 3.11-10 |
| p | E212-P232 | 43.792 | 1.24-03 | 1.58+01 | 7.89-05 | 2.49-03 | 6.99-05 | 6.99-05 |
| o | E212-P234 | 43.794 | 2.48-03 | 1.58+01 | 1.57-04 | 4.95-03 | 1.39-04 | 1.39-04 |
| α | F212-S212 | 39.615 | | | | | 1.19-01 | 1.19-01 |
| β | M232-S212 | 40.306 | | | | | 1.26-06 | 1.26-06 |
| χ | M432-S212 | 40.825 | | | | | 1.37-06 | 1.37-06 |
| δ | E212-S212 | 42.528 | | | | | 8.81-01 | 8.81-01 |

| Z=7 Transition | | WL | Ar | Γ | K | Qd | A' | A'' |
|-----------------------|-----------|-----------|-----------|----------------------------|----------|-----------|-----------|------------|
| n | F212-P232 | 29.060 | 2.33-02 | 2.38+00 | 9.52-03 | 4.52-02 | 1.09-03 | 1.09-03 |
| m | F212-P234 | 29.062 | 4.83-02 | 2.38+00 | 1.97-02 | 9.38-02 | 2.25-03 | 2.25-03 |
| d | M232-P232 | 29.498 | 1.64-01 | 2.73-05 | 6.69-01 | 3.65-05 | 2.01-06 | 2.01-06 |
| c | M232-P234 | 29.500 | 8.10-02 | 2.73-05 | 3.31-01 | 1.81-05 | 9.96-07 | 9.96-07 |
| i | M432-P232 | 29.875 | 1.60-06 | 3.96-06 | 2.86-01 | 2.27-06 | 1.14-06 | 1.14-06 |
| h | M432-P234 | 29.877 | 1.24-08 | 3.96-06 | 2.22-03 | 1.76-08 | 8.86-09 | 8.86-09 |
| p | E212-P232 | 30.955 | 2.57-03 | 1.57+01 | 1.64-04 | 5.14-03 | 1.45-04 | 1.45-04 |
| o | E212-P234 | 30.958 | 5.09-03 | 1.57+01 | 3.24-04 | 1.02-02 | 2.87-04 | 2.87-04 |
| α | F212-S212 | 28.373 | | | | | 1.14-01 | 1.14-01 |
| β | M232-S212 | 28.790 | | | | | 3.81-06 | 3.81-06 |
| χ | M432-S212 | 29.149 | | | | | 3.99-06 | 3.99-06 |
| δ | E212-S212 | 30.176 | | | | | 8.86-01 | 8.86-01 |

Table 3 (continued) a) 1s-2s excitation

| Z=8 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|------------|-------------------|-----------|-----------|----------------------------|----------|-----------|-----------|------------|
| n | F212-P232 | 21.781 | 4.27-02 | 2.44+00 | 1.66-02 | 8.09-02 | 1.84-03 | 1.84-03 |
| m | F212-P234 | 21.784 | 9.05-02 | 2.44+00 | 3.52-02 | 1.72-01 | 3.91-03 | 3.91-03 |
| d | M232-P232 | 22.065 | 3.03-01 | 7.41-05 | 6.70-01 | 9.94-05 | 6.46-06 | 6.46-06 |
| c | M232-P234 | 22.068 | 1.49-01 | 7.41-05 | 3.30-01 | 4.89-05 | 3.18-06 | 3.18-06 |
| i | M432-P232 | 22.331 | 6.60-06 | 8.61-06 | 4.31-01 | 7.42-06 | 4.24-06 | 4.24-06 |
| h | M432-P234 | 22.333 | 9.64-08 | 8.61-06 | 6.29-03 | 1.08-07 | 6.19-08 | 6.19-08 |
| p | E212-P232 | 23.029 | 4.76-03 | 1.56+01 | 3.04-04 | 9.51-03 | 2.70-04 | 2.70-04 |
| o | E212-P234 | 23.032 | 9.36-03 | 1.56+01 | 5.98-04 | 1.87-02 | 5.32-04 | 5.32-04 |
| α | F212-S212 | 21.322 | | | | | 1.11-01 | 1.11-01 |
| β | M232-S212 | 21.594 | | | | | 9.64-06 | 9.64-06 |
| χ | M432-S212 | 21.848 | | | | | 9.85-06 | 9.85-06 |
| δ | E212-S212 | 22.516 | | | | | 8.89-01 | 8.89-01 |

| Z=10 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------------------------|----------|-----------|-----------|------------|
| n | F212-P232 | 13.537 | 1.12-01 | 2.53+00 | 3.87-02 | 1.96-01 | 4.14-03 | 4.14-03 |
| m | F212-P234 | 13.540 | 2.54-01 | 2.53+00 | 8.79-02 | 4.44-01 | 9.41-03 | 9.41-03 |
| d | M232-P232 | 13.676 | 8.34-01 | 3.68-04 | 6.74-01 | 4.96-04 | 2.90-05 | 2.90-05 |
| c | M232-P234 | 13.679 | 4.03-01 | 3.68-04 | 3.25-01 | 2.39-04 | 1.40-05 | 1.40-05 |
| i | M432-P232 | 13.820 | 7.10-05 | 3.32-05 | 6.70-01 | 4.44-05 | 2.88-05 | 2.88-05 |
| h | M432-P234 | 13.823 | 1.79-06 | 3.32-05 | 1.69-02 | 1.12-06 | 7.18-07 | 7.18-07 |
| p | E212-P232 | 14.161 | 1.31-02 | 1.56+01 | 8.37-04 | 2.60-02 | 7.47-04 | 7.47-04 |
| o | E212-P234 | 14.164 | 2.52-02 | 1.56+01 | 1.62-03 | 5.03-02 | 1.45-03 | 1.45-03 |
| α | F212-S212 | 13.302 | | | | | 1.07-01 | 1.07-01 |
| β | M232-S212 | 13.437 | | | | | 4.30-05 | 4.30-05 |
| χ | M432-S212 | 13.576 | | | | | 4.30-05 | 4.30-05 |
| δ | E212-S212 | 13.905 | | | | | 8.93-01 | 8.93-01 |

| Z=12 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------------------------|----------|-----------|-----------|------------|
| n | F212-P232 | 9.2189 | 2.34-01 | 2.60+00 | 6.83-02 | 3.55-01 | 6.52-03 | 6.52-03 |
| m | F212-P234 | 9.2223 | 5.89-01 | 2.60+00 | 1.72-01 | 8.95-01 | 1.77-02 | 1.77-02 |
| d | M232-P232 | 9.2980 | 1.88+00 | 1.29-03 | 6.81-01 | 1.75-03 | 9.40-05 | 9.40-05 |
| c | M232-P234 | 9.3015 | 8.81-01 | 1.29-03 | 3.19-01 | 8.21-04 | 4.40-05 | 4.40-05 |
| i | M432-P232 | 9.3838 | 4.97-04 | 1.07-04 | 8.03-01 | 1.71-04 | 1.11-04 | 1.11-04 |
| h | M432-P234 | 9.3874 | 1.53-05 | 1.07-04 | 2.47-02 | 5.26-06 | 3.41-06 | 3.41-06 |
| p | E212-P232 | 9.5762 | 2.93-02 | 1.55+01 | 1.89-03 | 5.84-02 | 1.70-03 | 1.70-03 |
| o | E212-P234 | 9.5799 | 5.50-02 | 1.55+01 | 3.54-03 | 1.09-01 | 3.18-03 | 3.18-03 |
| α | F212-S212 | 9.0834 | | | | | 1.03-01 | 1.03-01 |
| β | M232-S212 | 9.1603 | | | | | 1.38-04 | 1.38-04 |
| χ | M432-S212 | 9.2435 | | | | | 1.38-04 | 1.38-04 |
| δ | E212-S212 | 9.4301 | | | | | 8.97-01 | 8.97-01 |

Table 3 (continued) a) 1s-2s excitation

| Z=13 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|----------|------------|--------|---------|----------|---------|---------|---------|---------|
| n | F212-P232 | 7.7960 | 3.16-01 | 2.64+00 | 8.30-02 | 4.38-01 | 8.38-03 | 8.38-03 |
| m | F212-P234 | 7.7996 | 8.55-01 | 2.64+00 | 2.24-01 | 1.18+00 | 2.26-02 | 2.26-02 |
| d | M232-P232 | 7.8581 | 2.68+00 | 2.20-03 | 6.85-01 | 3.01-03 | 1.55-04 | 1.55-04 |
| c | M232-P234 | 7.8617 | 1.23+00 | 2.20-03 | 3.15-01 | 1.38-03 | 7.12-05 | 7.12-05 |
| i | M432-P232 | 7.9262 | 1.17-03 | 1.82-04 | 8.42-01 | 3.07-04 | 1.93-04 | 1.93-04 |
| h | M432-P234 | 7.9299 | 3.72-05 | 1.82-04 | 2.68-02 | 9.76-06 | 6.14-06 | 6.14-06 |
| p | E212-P232 | 8.0764 | 4.17-02 | 1.54+01 | 2.68-03 | 8.28-02 | 2.41-03 | 2.41-03 |
| o | E212-P234 | 8.0802 | 7.68-02 | 1.54+01 | 4.94-03 | 1.52-01 | 4.44-03 | 4.44-03 |
| α | F212-S212 | 7.6895 | | | | | 1.01-01 | 1.01-01 |
| β | M232-S212 | 7.7499 | | | | | 2.26-04 | 2.26-04 |
| χ | M432-S212 | 7.8162 | | | | | 2.29-04 | 2.29-04 |
| δ | E212-S212 | 7.9622 | | | | | 8.99-01 | 8.99-01 |

| Z=14 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|----------|------------|--------|---------|----------|---------|---------|---------|---------|
| n | F212-P232 | 6.6783 | 4.12-01 | 2.67+00 | 9.60-02 | 5.13-01 | 9.50-03 | 9.50-03 |
| m | F212-P234 | 6.6820 | 1.21+00 | 2.67+00 | 2.81-01 | 1.50+00 | 2.78-02 | 2.78-02 |
| d | M232-P232 | 6.7280 | 3.72+00 | 3.57-03 | 6.89-01 | 4.92-03 | 2.43-04 | 2.43-04 |
| c | M232-P234 | 6.7317 | 1.67+00 | 3.57-03 | 3.10-01 | 2.21-03 | 1.09-04 | 1.09-04 |
| i | M432-P232 | 6.7830 | 2.59-03 | 3.04-04 | 8.70-01 | 5.29-04 | 3.15-04 | 3.15-04 |
| h | M432-P234 | 6.7868 | 8.26-05 | 3.04-04 | 2.78-02 | 1.69-05 | 1.01-05 | 1.01-05 |
| p | E212-P232 | 6.9027 | 5.78-02 | 1.54+01 | 3.71-03 | 1.14-01 | 3.34-03 | 3.34-03 |
| o | E212-P234 | 6.9066 | 1.04-01 | 1.54+01 | 6.68-03 | 2.06-01 | 6.01-03 | 6.01-03 |
| α | F212-S212 | 6.5931 | | | | | 9.90-02 | 9.90-02 |
| β | M232-S212 | 6.6414 | | | | | 3.52-04 | 3.52-04 |
| χ | M432-S212 | 6.6951 | | | | | 3.62-04 | 3.62-04 |
| δ | E212-S212 | 6.8116 | | | | | 9.00-01 | 9.00-01 |

| Z=16 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|----------|------------|--------|---------|----------|---------|---------|---------|---------|
| n | F212-P232 | 5.0581 | 6.34-01 | 2.75+00 | 1.12-01 | 6.16-01 | 1.06-02 | 1.06-02 |
| m | F212-P234 | 5.0619 | 2.27+00 | 2.75+00 | 4.02-01 | 2.21+00 | 3.80-02 | 3.80-02 |
| d | M232-P232 | 5.0917 | 6.69+00 | 8.31-03 | 7.01-01 | 1.17-02 | 5.30-04 | 5.30-04 |
| c | M232-P234 | 5.0956 | 2.85+00 | 8.31-03 | 2.98-01 | 4.96-03 | 2.25-04 | 2.25-04 |
| i | M432-P232 | 5.1290 | 1.09-02 | 7.93-04 | 9.07-01 | 1.44-03 | 7.38-04 | 7.38-04 |
| h | M432-P234 | 5.1330 | 3.24-04 | 7.93-04 | 2.70-02 | 4.29-05 | 2.20-05 | 2.20-05 |
| p | E212-P232 | 5.2090 | 1.04-01 | 1.53+01 | 6.64-03 | 2.03-01 | 6.00-03 | 6.00-03 |
| o | E212-P234 | 5.2131 | 1.77-01 | 1.53+01 | 1.13-02 | 3.47-01 | 1.02-02 | 1.02-02 |
| α | F212-S212 | 5.0009 | | | | | 9.46-02 | 9.46-02 |
| β | M232-S212 | 5.0338 | | | | | 7.56-04 | 7.56-04 |
| χ | M432-S212 | 5.0702 | | | | | 8.13-04 | 8.13-04 |
| δ | E212-S212 | 5.1484 | | | | | 9.04-01 | 9.04-01 |

Table 3 (continued) a) 1s-2s excitation

| Z=20 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------|----------|-----------|-----------|------------|
| n | F212-P232 | 3.1855 | 1.06+00 | 2.92+00 | 9.88-02 | 5.77-01 | 8.23-03 | 8.23-03 |
| m | F212-P234 | 3.1897 | 6.73+00 | 2.92+00 | 6.28-01 | 3.67+00 | 5.23-02 | 5.23-02 |
| d | M232-P232 | 3.2039 | 1.78+01 | 3.02-02 | 7.29-01 | 4.40-02 | 1.65-03 | 1.65-03 |
| c | M232-P234 | 3.2081 | 6.61+00 | 3.02-02 | 2.70-01 | 1.63-02 | 5.13-04 | 5.13-04 |
| i | M432-P232 | 3.2234 | 1.23-01 | 4.34-03 | 9.48-01 | 8.23-03 | 2.78-03 | 2.78-03 |
| h | M432-P234 | 3.2276 | 2.40-03 | 4.34-03 | 1.85-02 | 1.60-04 | 5.42-05 | 5.42-05 |
| p | E212-P232 | 3.2651 | 2.75-01 | 1.51+01 | 1.74-02 | 5.26-01 | 1.59-02 | 1.59-02 |
| o | E212-P234 | 3.2695 | 4.02-01 | 1.51+01 | 2.54-02 | 7.69-01 | 2.31-02 | 2.31-02 |
| α | F212-S212 | 3.1562 | | | | | 8.33-02 | 8.33-02 |
| β | M232-S212 | 3.1742 | | | | | 2.27-03 | 2.27-03 |
| χ | M432-S212 | 3.1934 | | | | | 2.93-03 | 2.93-03 |
| δ | E212-S212 | 3.2343 | | | | | 9.11-01 | 9.11-01 |
| Z=22 | | | | | | | | |
| Z=22 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
| n | F212-P232 | 2.6159 | 1.17+00 | 3.01+00 | 7.82-02 | 4.71-01 | 5.97-03 | 5.97-03 |
| m | F212-P234 | 2.6201 | 1.08+01 | 3.01+00 | 7.20-01 | 4.34+00 | 5.50-02 | 5.50-02 |
| d | M232-P232 | 2.6305 | 2.69+01 | 4.84-02 | 7.43-01 | 7.19-02 | 2.43-03 | 2.43-03 |
| c | M232-P234 | 2.6348 | 9.26+00 | 4.84-02 | 2.56-01 | 2.47-02 | 8.37-04 | 8.37-04 |
| i | M432-P232 | 2.6454 | 3.48-01 | 9.13-03 | 9.62-01 | 1.76-02 | 4.70-03 | 4.70-03 |
| h | M432-P234 | 2.6497 | 4.72-03 | 9.13-03 | 1.30-02 | 2.38-04 | 6.36-05 | 6.36-05 |
| p | E212-P232 | 2.6772 | 4.18-01 | 1.50+01 | 2.61-02 | 7.84-01 | 2.39-02 | 2.39-02 |
| o | E212-P234 | 2.6816 | 5.52-01 | 1.50+01 | 3.46-02 | 1.04+00 | 3.17-02 | 3.17-02 |
| α | F212-S212 | 2.5938 | | | | | 7.64-02 | 7.64-02 |
| β | M232-S212 | 2.6082 | | | | | 3.27-03 | 3.27-03 |
| χ | M432-S212 | 2.6227 | | | | | 4.89-03 | 4.89-03 |
| δ | E212-S212 | 2.6541 | | | | | 9.15-01 | 9.15-01 |
| Z=26 | | | | | | | | |
| Z=26 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
| n | F212-P232 | 1.8523 | 1.09+00 | 3.21+00 | 3.82-02 | 2.45-01 | 2.33-03 | 2.33-03 |
| m | F212-P234 | 1.8566 | 2.43+01 | 3.21+00 | 8.50-01 | 5.46+00 | 5.28-02 | 5.28-02 |
| d | M232-P232 | 1.8628 | 5.44+01 | 9.08-02 | 7.67-01 | 1.39-01 | 3.68-03 | 3.68-03 |
| c | M232-P234 | 1.8672 | 1.65+01 | 9.08-02 | 2.32-01 | 4.21-02 | 1.11-03 | 1.11-03 |
| i | M432-P232 | 1.8722 | 2.10+00 | 3.24-02 | 9.81-01 | 6.35-02 | 1.08-02 | 1.08-02 |
| h | M432-P234 | 1.8766 | 9.30-03 | 3.24-02 | 4.35-03 | 2.82-04 | 4.76-05 | 4.76-05 |
| p | E212-P232 | 1.8924 | 8.75-01 | 1.47+01 | 5.29-02 | 1.56+00 | 4.88-02 | 4.88-01 |
| o | E212-P234 | 1.8969 | 9.07-01 | 1.47+01 | 5.49-02 | 1.62+00 | 5.07-02 | 5.07-02 |
| α | F212-S212 | 1.8388 | | | | | 6.10-02 | 6.10-02 |
| β | M232-S212 | 1.8491 | | | | | 4.80-03 | 4.80-03 |
| χ | M432-S212 | 1.8584 | | | | | 1.10-02 | 1.10-02 |
| δ | E212-S212 | 1.8783 | | | | | 9.23-01 | 9.23-01 |

Table 3 (continued) a) 1s-2s excitation

| Z=28 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------|----------|-----------|-----------|------------|
| n | F212-P232 | 1.5892 | 9.50-01 | 3.31+00 | 2.44-02 | 1.62-01 | 1.30-03 | 1.30-03 |
| m | F212-P234 | 1.5936 | 3.46+01 | 3.31+00 | 8.90-01 | 5.90+00 | 4.73-02 | 4.73-02 |
| d | M232-P232 | 1.5984 | 7.32+01 | 1.08-01 | 7.74-01 | 1.67-01 | 3.83-03 | 3.83-03 |
| c | M232-P234 | 1.6029 | 2.13+01 | 1.08-01 | 2.25-01 | 4.86-02 | 1.13-03 | 1.13-03 |
| i | M432-P232 | 1.6063 | 4.49+00 | 5.44-02 | 9.86-01 | 1.07-01 | 1.49-02 | 1.49-02 |
| h | M432-P234 | 1.6108 | 8.61-03 | 5.44-02 | 1.89-03 | 2.06-04 | 2.85-05 | 2.85-05 |
| p | E212-P232 | 1.6229 | 1.22+00 | 1.46+01 | 7.21-02 | 2.10+00 | 6.68-02 | 6.68-02 |
| o | E212-P234 | 1.6275 | 1.10+00 | 1.46+01 | 6.48-02 | 1.89+00 | 6.01-02 | 6.01-02 |
| α | F212-S212 | 1.5783 | | | | | 5.31-02 | 5.31-02 |
| β | M232-S212 | 1.5875 | | | | | 4.95-03 | 4.95-03 |
| χ | M432-S212 | 1.5953 | | | | | 1.51-02 | 1.51-02 |
| δ | E212-S212 | 1.6116 | | | | | 9.27-01 | 9.27-01 |

| Z=30 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------|----------|-----------|-----------|------------|
| n | F212-P232 | 1.3777 | 7.81-01 | 3.42+00 | 1.51-02 | 1.03-01 | 6.90-04 | 6.90-04 |
| m | F212-P234 | 1.3821 | 4.77+01 | 3.42+00 | 9.19-01 | 6.29+00 | 4.20-02 | 4.20-02 |
| d | M232-P232 | 1.3861 | 9.56+01 | 1.18-01 | 7.77-01 | 1.83-01 | 3.61-03 | 3.61-03 |
| c | M232-P234 | 1.3906 | 2.73+01 | 1.18-01 | 2.22-01 | 5.24-02 | 1.03-03 | 1.03-03 |
| i | M432-P232 | 1.3929 | 8.80+00 | 8.45-02 | 9.90-01 | 1.67-01 | 1.94-02 | 1.94-02 |
| h | M432-P234 | 1.3974 | 5.18-03 | 8.45-02 | 5.83-04 | 9.84-05 | 1.14-05 | 1.14-05 |
| p | E212-P232 | 1.4067 | 1.66+00 | 1.45+01 | 9.55-02 | 2.76+00 | 8.88-02 | 8.88-02 |
| o | E212-P234 | 1.4113 | 1.28+00 | 1.45+01 | 7.37-02 | 2.13+00 | 6.85-02 | 6.85-02 |
| α | F212-S212 | 1.3689 | | | | | 4.57-02 | 4.57-02 |
| β | M232-S212 | 1.3771 | | | | | 4.64-03 | 4.64-03 |
| χ | M432-S212 | 1.3839 | | | | | 1.96-02 | 1.96-02 |
| δ | E212-S212 | 1.3975 | | | | | 9.30-01 | 9.30-01 |

| Z=32 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------|----------|-----------|-----------|------------|
| n | F212-P232 | 1.2052 | 6.18-01 | 3.53+00 | 9.09-03 | 6.41-02 | 2.80-04 | 2.80-04 |
| m | F212-P234 | 1.2097 | 6.39+01 | 3.53+00 | 9.39-01 | 6.63+00 | 2.89-02 | 2.89-02 |
| d | M232-P232 | 1.2129 | 1.22+02 | 1.20-01 | 7.77-01 | 1.86-01 | 3.10-03 | 3.10-03 |
| c | M232-P234 | 1.2174 | 3.48+01 | 1.20-01 | 2.23-01 | 5.34-02 | 8.90-04 | 8.90-04 |
| i | M432-P232 | 1.2190 | 1.59+01 | 1.22-01 | 9.92-01 | 2.42-01 | 2.39-02 | 2.39-02 |
| h | M432-P234 | 1.2236 | 1.18-03 | 1.22-01 | 7.38-05 | 1.80-05 | 1.78-06 | 1.78-06 |
| p | E212-P232 | 1.2307 | 2.23+00 | 1.43+01 | 1.24-01 | 3.54+00 | 1.16-01 | 1.16-01 |
| o | E212-P234 | 1.2353 | 1.46+00 | 1.43+01 | 8.11-02 | 2.32+00 | 7.57-02 | 7.57-02 |
| α | F212-S212 | 1.1979 | | | | | 3.88-02 | 3.88-02 |
| β | M232-S212 | 1.2055 | | | | | 3.99-03 | 3.99-03 |
| χ | M432-S212 | 1.2116 | | | | | 2.41-02 | 2.41-02 |
| δ | E212-S212 | 1.2231 | | | | | 9.33-01 | 9.33-01 |

Table 3 (continued) a) 1s-2s excitation

| Z=34 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------------------------|----------|-----------|-----------|------------|
| n | F212-P232 | 1.0627 | 4.77-01 | 3.64+00 | 5.44-03 | 3.96-02 | 1.78-04 | 1.78-04 |
| m | F212-P234 | 1.0672 | 8.35+01 | 3.64+00 | 9.53-01 | 6.94+00 | 3.12-02 | 3.12-02 |
| d | M232-P232 | 1.0699 | 1.51+02 | 1.15-01 | 7.73-01 | 1.78-01 | 2.47-03 | 2.47-03 |
| c | M232-P234 | 1.0744 | 4.42+01 | 1.15-01 | 2.26-01 | 5.19-02 | 7.23-04 | 7.23-04 |
| i | M432-P232 | 1.0755 | 2.64+01 | 1.65-01 | 9.94-01 | 3.27-01 | 2.82-02 | 2.82-02 |
| h | M432-P234 | 1.0801 | 2.63-04 | 1.65-01 | 9.89-06 | 3.26-06 | 2.81-07 | 2.81-07 |
| p | E212-P232 | 1.0854 | 2.93+00 | 1.42+01 | 1.57-01 | 4.43+00 | 1.47-01 | 1.47-01 |
| o | E212-P234 | 1.0901 | 1.62+00 | 1.42+01 | 8.66-02 | 2.45+00 | 8.11-02 | 8.11-02 |
| α | F212-S212 | 1.0566 | | | | | 3.27-02 | 3.27-02 |
| β | M232-S212 | 1.0637 | | | | | 3.20-03 | 3.20-03 |
| χ | M432-S212 | 1.0693 | | | | | 2.84-02 | 2.84-02 |
| δ | E212-S212 | 1.0791 | | | | | 9.36-01 | 9.36-01 |

| Z=36 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------------------------|----------|-----------|-----------|------------|
| n | F212-P232 | .94354 | 3.63-01 | 3.75+00 | 3.27-03 | 2.45-02 | 8.07-05 | 8.07-05 |
| m | F212-P234 | .94804 | 1.07+02 | 3.75+00 | 9.63-01 | 7.22+00 | 2.38-02 | 2.38-02 |
| d | M232-P232 | .95033 | 1.85+02 | 1.05-01 | 7.68-01 | 1.61-01 | 1.85-03 | 1.85-03 |
| c | M232-P234 | .95490 | 5.59+01 | 1.05-01 | 2.32-01 | 4.86-02 | 5.61-04 | 5.61-04 |
| i | M432-P232 | .95565 | 4.11+01 | 2.10-01 | 9.95-01 | 4.18-01 | 3.20-02 | 3.20-02 |
| h | M432-P234 | .96026 | 5.47-03 | 2.10-01 | 1.32-04 | 5.56-05 | 4.25-06 | 4.25-06 |
| p | E212-P232 | .96418 | 3.80+00 | 1.40+01 | 1.94-01 | 5.44+00 | 1.82-01 | 1.82-01 |
| o | E212-P234 | .96887 | 1.76+00 | 1.40+01 | 9.00-02 | 2.52+00 | 8.44-02 | 8.44-02 |
| α | F212-S212 | .93838 | | | | | 2.74-02 | 2.74-02 |
| β | M232-S212 | .94509 | | | | | 2.42-03 | 2.42-03 |
| χ | M432-S212 | .95034 | | | | | 3.22-02 | 3.22-02 |
| δ | E212-S212 | .95878 | | | | | 9.38-01 | 9.38-01 |

| Z=42 | Transition | WL | Ar | Γ | K | Qd | A' | A'' |
|-------------|-------------------|-----------|-----------|----------------------------|----------|-----------|-----------|------------|
| n | F212-P232 | .68361 | 1.68-01 | 4.05+00 | 7.99-04 | 6.47-03 | 1.26-05 | 1.26-05 |
| m | F212-P234 | .68812 | 2.06+02 | 4.05+00 | 9.80-01 | 7.94+00 | 1.55-02 | 1.55-02 |
| d | M232-P232 | .68957 | 3.21+02 | 6.66-02 | 7.47-01 | 9.94-02 | 6.22-04 | 6.22-04 |
| c | M232-P234 | .69416 | 1.09+02 | 6.66-02 | 2.53-01 | 3.37-02 | 2.11-04 | 2.11-04 |
| i | M432-P232 | .69444 | 1.15+02 | 3.42-01 | 9.97-01 | 6.81-01 | 4.00-02 | 4.00-02 |
| h | M432-P234 | .69909 | 6.01-02 | 3.42-01 | 5.20-04 | 3.55-04 | 2.09-04 | 2.09-04 |
| p | E212-P232 | .70016 | 7.63+00 | 1.36+01 | 3.27-01 | 8.92+00 | 3.08-01 | 3.08-01 |
| o | E212-P234 | .70489 | 2.06+00 | 1.36+01 | 8.82-02 | 2.40+00 | 8.32-02 | 8.32-01 |
| α | F212-S212 | .68031 | | | | | 1.58-02 | 1.58-02 |
| β | M232-S212 | .68622 | | | | | 8.53-04 | 8.53-04 |
| χ | M432-S212 | .69104 | | | | | 4.01-02 | 4.01-02 |
| δ | E212-S212 | .69670 | | | | | 9.43-01 | 9.43-01 |

Table 4. Cross section (σ_C) for $1s^2 2s - 1s 2s 2p$ excitation of Li-like ions:

$$\sigma = \sigma_{CX} \frac{a_0^2}{Z_S^4} (\text{cm}^2), E = 13.6 Z_S^2 (\Delta \epsilon + u) (\text{ev})$$

Designations: $q = 2s 2p(^3P) 1s^2 P_{3/2} - 1s^2 2s^2 S_{1/2}$, $r = 2s 2p(^3P) 1s^2 P_{1/2} - 1s^2 2s^2 S_{1/2}$,

$s = 2s 2p(^1P) 1s^2 P_{3/2} - 1s^2 2s^2 S_{1/2}$, $t = 2s 2p(^1P) 1s^2 P_{1/2} - 1s^2 2s^2 S_{1/2}$,

$u = 2s 2p(^3P) 1s^4 P_{3/2} - 1s^2 2s^2 S_{1/2}$, $v = 2s 2p(^3P) 1s^4 P_{1/2} - 1s^2 2s^2 S_{1/2}$.

| Z_S/Z_N | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 |
|-----------|--------|--------|--------|--------|--------|--------|
| u | q | r | s | t | u | v |
| 0.01 | 1.49-1 | 7.40-2 | 6.30-2 | 3.20-2 | 5.46-2 | 2.73-2 |
| 0.02 | 1.50-1 | 7.45-2 | 6.29-2 | 3.20-2 | 5.43-2 | 2.72-2 |
| 0.04 | 1.52-1 | 7.57-2 | 6.24-2 | 3.17-2 | 5.35-2 | 2.68-2 |
| 0.08 | 1.55-1 | 7.72-2 | 6.07-2 | 3.09-2 | 5.13-2 | 2.57-2 |
| 0.16 | 1.62-1 | 8.04-2 | 5.81-2 | 2.96-2 | 4.78-2 | 2.39-2 |
| 0.32 | 1.76-1 | 8.75-2 | 5.27-2 | 2.70-2 | 4.05-2 | 2.03-2 |
| 0.64 | 2.03-1 | 1.01-1 | 4.42-2 | 2.30-2 | 2.84-2 | 1.42-2 |
| 1.28 | 2.41-1 | 1.20-1 | 3.48-2 | 1.85-2 | 1.44-2 | 7.22-3 |
| 2.56 | 2.43-1 | 1.21-1 | 2.56-2 | 1.40-2 | 4.02-3 | 2.01-3 |
| 5.12 | 2.14-1 | 1.06-1 | 2.03-2 | 1.12-2 | 1.10-3 | 5.47-4 |
| 10.24 | 1.67-1 | 8.28-2 | 1.52-2 | 8.41-3 | 1.50-4 | 7.47-5 |

| Z_S/Z_N | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 |
|-----------|--------|--------|--------|--------|--------|--------|
| u | q | r | s | t | u | v |
| 0.01 | 2.07-1 | 1.03-1 | 9.81-2 | 4.94-2 | 8.66-2 | 4.33-2 |
| 0.02 | 2.07-1 | 1.03-1 | 9.66-2 | 4.87-2 | 8.49-2 | 4.25-2 |
| 0.04 | 2.11-1 | 1.05-1 | 9.53-2 | 4.81-2 | 8.30-2 | 4.15-2 |
| 0.08 | 2.19-1 | 1.09-1 | 9.23-2 | 4.66-2 | 7.89-2 | 3.95-2 |
| 0.16 | 2.33-1 | 1.16-1 | 8.60-2 | 4.35-2 | 7.03-2 | 3.52-2 |
| 0.32 | 2.60-1 | 1.29-1 | 7.65-2 | 3.89-2 | 5.70-2 | 2.85-2 |
| 0.64 | 2.99-1 | 1.48-1 | 6.20-2 | 3.18-2 | 3.69-2 | 1.85-2 |
| 1.28 | 3.34-1 | 1.65-1 | 4.75-2 | 2.47-2 | 1.72-2 | 8.59-3 |
| 2.56 | 3.34-1 | 1.65-1 | 3.60-2 | 1.90-2 | 4.45-3 | 2.22-3 |
| 5.12 | 2.87-1 | 1.42-1 | 2.85-2 | 1.52-2 | 1.12-3 | 5.57-4 |
| 10.24 | 2.19-1 | 1.08-1 | 2.11-2 | 1.12-2 | 1.50-4 | 7.40-5 |

Table 4. (continued)

| | | | | | | |
|-----------|--------|--------|--------|--------|--------|--------|
| Z_S/Z_N | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 |
| u | q | r | s | t | u | v |
| 0.01 | 2.65-1 | 1.32-1 | 1.29-1 | 6.52-2 | 1.15-1 | 5.73-2 |
| 0.02 | 2.67-1 | 1.33-1 | 1.27-1 | 6.45-2 | 1.13-1 | 5.64-2 |
| 0.04 | 2.73-1 | 1.36-1 | 1.24-1 | 6.30-2 | 1.09-1 | 5.44-2 |
| 0.08 | 2.86-1 | 1.42-1 | 1.20-1 | 6.11-2 | 1.03-1 | 5.16-2 |
| 0.16 | 3.06-1 | 1.52-1 | 1.10-1 | 5.62-2 | 8.99-2 | 4.50-2 |
| 0.32 | 3.42-1 | 1.70-1 | 9.56-2 | 4.93-2 | 7.02-2 | 3.51-2 |
| 0.64 | 3.90-1 | 1.93-1 | 7.57-2 | 3.97-2 | 4.34-2 | 2.17-2 |
| 1.28 | 4.33-1 | 2.14-1 | 5.75-2 | 3.10-2 | 1.89-2 | 9.42-3 |
| 2.56 | 4.22-1 | 2.09-1 | 4.37-2 | 2.41-2 | 4.70-3 | 2.35-3 |
| 5.12 | 3.51-1 | 1.73-1 | 3.38-2 | 1.88-2 | 1.13-3 | 5.60-4 |
| 10.24 | 2.64-1 | 1.30-1 | 2.48-2 | 1.38-2 | 1.55-4 | 7.44-5 |
| Z_S/Z_N | 8/10 | 8/10 | 8/10 | 8/10 | 8/10 | 8/10 |
| u | q | r | s | t | u | v |
| 0.01 | 3.80-1 | 1.87-1 | 1.79-1 | 9.22-2 | 1.60-1 | 8.01-2 |
| 0.02 | 3.85-1 | 1.90-1 | 1.77-1 | 9.11-2 | 1.57-1 | 7.85-2 |
| 0.04 | 3.93-1 | 1.94-1 | 1.72-1 | 8.87-2 | 1.51-1 | 7.54-2 |
| 0.08 | 4.13-1 | 2.03-1 | 1.64-1 | 8.50-2 | 1.40-1 | 7.00-2 |
| 0.16 | 4.44-1 | 2.18-1 | 1.48-1 | 7.78-2 | 1.20-1 | 6.00-2 |
| 0.32 | 4.92-1 | 2.41-1 | 1.25-1 | 6.68-2 | 8.93-2 | 4.47-2 |
| 0.64 | 5.56-1 | 2.72-1 | 9.69-2 | 5.40-2 | 5.27-2 | 2.63-2 |
| 1.28 | 5.87-1 | 2.86-1 | 7.06-2 | 4.15-2 | 2.09-2 | 1.04-2 |
| 2.56 | 5.57-1 | 2.71-1 | 5.34-2 | 3.28-2 | 5.05-3 | 2.50-3 |
| 5.12 | 4.55-1 | 2.22-1 | 4.10-2 | 2.55-2 | 1.17-3 | 5.67-4 |
| 10.24 | 3.34-1 | 1.63-1 | 2.95-2 | 1.84-2 | 1.87-4 | 7.92-5 |
| Z_S/Z_N | 10/12 | 10/12 | 10/12 | 10/12 | 10/12 | 10/12 |
| u | q | r | s | t | u | v |
| 0.01 | 4.84-1 | 2.36-1 | 2.16-1 | 1.14-1 | 1.94-1 | 9.68-2 |
| 0.02 | 4.89-1 | 2.38-1 | 2.13-1 | 1.13-1 | 1.90-1 | 9.49-2 |
| 0.04 | 5.02-1 | 2.44-1 | 2.07-1 | 1.10-1 | 1.82-1 | 9.09-2 |
| 0.08 | 5.25-1 | 2.55-1 | 1.95-1 | 1.05-1 | 1.67-1 | 8.34-2 |
| 0.16 | 5.65-1 | 2.73-1 | 1.74-1 | 9.54-2 | 1.41-1 | 7.02-2 |
| 0.32 | 6.23-1 | 3.00-1 | 1.43-1 | 8.18-2 | 1.02-1 | 5.09-2 |
| 0.64 | 6.90-1 | 3.31-1 | 1.07-1 | 6.61-2 | 5.73-2 | 2.86-2 |
| 1.28 | 7.15-1 | 3.42-1 | 7.66-2 | 5.21-2 | 2.23-2 | 1.11-2 |
| 2.56 | 6.65-1 | 3.18-1 | 5.70-2 | 4.17-2 | 5.35-3 | 2.59-3 |
| 5.12 | 5.33-1 | 2.55-1 | 4.30-2 | 3.21-2 | 1.32-3 | 5.90-4 |
| 10.24 | 3.88-1 | 1.86-1 | 3.07-2 | 2.31-2 | 2.97-4 | 9.94-5 |

Table 4 (continued)

| | | | | | | |
|-----------|--------|--------|--------|--------|--------|--------|
| Z_S/Z_N | 26/28 | 26/28 | 26/28 | 26/28 | 26/28 | 26/28 |
| u | q | r | s | t | u | v |
| 0.01 | 9.05-1 | 3.35-1 | 2.92-1 | 2.75-1 | 3.23-1 | 1.51-1 |
| 0.02 | 9.12-1 | 3.35-1 | 2.81-1 | 2.74-1 | 3.14-1 | 1.46-1 |
| 0.04 | 9.35-1 | 3.39-1 | 2.67-1 | 2.74-1 | 3.02-1 | 1.39-1 |
| 0.08 | 9.69-1 | 3.44-1 | 2.39-1 | 2.73-1 | 2.76-1 | 1.26-1 |
| 0.16 | 1.03+0 | 3.54-1 | 1.94-1 | 2.73-1 | 2.36-1 | 1.04-1 |
| 0.32 | 1.11+0 | 3.67-1 | 1.33-1 | 2.72-1 | 1.81-1 | 7.39-2 |
| 0.64 | 1.18+0 | 3.77-1 | 6.82-2 | 2.69-1 | 1.23-1 | 4.24-2 |
| 1.28 | 1.18+0 | 3.68-1 | 2.40-2 | 2.55-1 | 8.05-2 | 2.04-2 |
| 2.56 | 1.01+0 | 3.12-1 | 5.15-3 | 2.14-1 | 5.42-2 | 9.84-3 |
| 5.12 | 7.96-1 | 2.45-1 | 1.07-3 | 1.67-1 | 3.97-2 | 6.25-3 |
| 10.24 | 5.66-1 | 1.74-1 | 1.49-4 | 1.19-1 | 2.76-2 | 4.14-3 |
| | | | | | | |
| Z_S/Z_N | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 |
| u | q | r | s | t | u | v |
| 0.01 | 9.18-1 | 3.25-1 | 2.95-1 | 2.96-1 | 3.38-1 | 1.54-1 |
| 0.02 | 9.25-1 | 3.26-1 | 2.86-1 | 2.95-1 | 3.31-1 | 1.50-1 |
| 0.04 | 9.47-1 | 3.28-1 | 2.72-1 | 2.97-1 | 3.18-1 | 1.43-1 |
| 0.08 | 9.81-1 | 3.32-1 | 2.43-1 | 2.97-1 | 2.93-1 | 1.29-1 |
| 0.16 | 1.04+0 | 3.39-1 | 1.98-1 | 3.00-1 | 2.55-1 | 1.07-1 |
| 0.32 | 1.12+0 | 3.48-1 | 1.35-1 | 3.02-1 | 2.01-1 | 7.68-2 |
| 0.64 | 1.20+0 | 3.56-1 | 7.09-2 | 3.04-1 | 1.46-1 | 4.57-2 |
| 1.28 | 1.18+0 | 3.41-1 | 2.65-2 | 2.88-1 | 1.02-1 | 2.34-2 |
| 2.56 | 1.02+0 | 2.91-1 | 7.49-3 | 2.44-1 | 7.36-2 | 1.25-2 |
| 5.12 | 7.96-1 | 2.27-1 | 2.90-3 | 1.90-1 | 5.48-2 | 8.35-3 |
| 10.24 | 5.65-1 | 1.61-1 | 1.45-3 | 1.35-1 | 3.83-2 | 5.63-3 |
| | | | | | | |
| Z_S/Z_N | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 |
| u | q | r | s | t | u | v |
| 0.01 | 9.17-1 | 3.16-1 | 3.00-1 | 3.14-1 | 3.56-1 | 1.58-1 |
| 0.02 | 9.26-1 | 3.17-1 | 2.93-1 | 3.14-1 | 3.50-1 | 1.54-1 |
| 0.04 | 9.45-1 | 3.18-1 | 2.77-1 | 3.15-1 | 3.36-1 | 1.46-1 |
| 0.08 | 9.76-1 | 3.20-1 | 2.49-1 | 3.17-1 | 3.12-1 | 1.32-1 |
| 0.16 | 1.03+0 | 3.24-1 | 2.03-1 | 3.22-1 | 2.75-1 | 1.10-1 |
| 0.32 | 1.11+0 | 3.31-1 | 1.41-1 | 3.27-1 | 2.24-1 | 8.03-2 |
| 0.64 | 1.17+0 | 3.33-1 | 7.74-2 | 3.29-1 | 1.70-1 | 4.92-2 |
| 1.28 | 1.16+0 | 3.17-1 | 3.28-2 | 3.14-1 | 1.27-1 | 2.68-2 |
| 2.56 | 1.00+0 | 2.72-1 | 1.30-2 | 2.69-1 | 9.61-2 | 1.56-2 |
| 5.12 | 7.78-1 | 2.10-1 | 7.16-3 | 2.08-1 | 7.17-2 | 1.07-2 |
| 10.24 | 5.54-1 | 1.49-1 | 4.50-3 | 1.48-1 | 5.05-2 | 7.30-3 |

Table 4. (continued)

| Z_S/Z_N | 11/13 | 11/13 | 11/13 | 11/13 | 11/13 | 11/13 |
|-----------|--------|--------|--------|--------|--------|--------|
| u | q | r | s | t | u | v |
| 0.01 | 5.28-1 | 2.56-1 | 2.31-1 | 1.24-1 | 2.08-1 | 1.04-1 |
| 0.02 | 5.34-1 | 2.59-1 | 2.27-1 | 1.22-1 | 2.02-1 | 1.01-1 |
| 0.04 | 5.49-1 | 2.66-1 | 2.20-1 | 1.19-1 | 1.94-1 | 9.70-2 |
| 0.08 | 5.72-1 | 2.76-1 | 2.06-1 | 1.13-1 | 1.77-1 | 8.84-2 |
| 0.16 | 6.15-1 | 2.96-1 | 1.83-1 | 1.03-1 | 1.48-1 | 7.41-2 |
| 0.32 | 6.78-1 | 3.25-1 | 1.49-1 | 8.91-2 | 1.07-1 | 5.33-2 |
| 0.64 | 7.44-1 | 3.55-1 | 1.09-1 | 7.24-2 | 5.93-2 | 2.95-2 |
| 1.28 | 7.74-1 | 3.68-1 | 7.78-2 | 5.84-2 | 2.29-2 | 1.13-2 |
| 2.56 | 7.10-1 | 3.37-1 | 5.70-2 | 4.68-2 | 5.61-3 | 2.66-3 |
| 5.12 | 5.64-1 | 2.68-1 | 4.25-2 | 3.59-2 | 1.46-3 | 6.15-4 |
| 10.24 | 4.09-1 | 1.94-1 | 3.03-2 | 2.57-2 | 4.08-4 | 1.20-4 |

| Z_S/Z_N | 12/14 | 12/14 | 12/14 | 12/14 | 12/14 | 12/14 |
|-----------|--------|--------|--------|--------|--------|--------|
| u | q | r | s | t | u | v |
| 0.01 | 5.72-1 | 2.74-1 | 2.42-1 | 1.33-1 | 2.19-1 | 1.09-1 |
| 0.02 | 5.80-1 | 2.78-1 | 2.38-1 | 1.31-1 | 2.14-1 | 1.07-1 |
| 0.04 | 5.94-1 | 2.84-1 | 2.30-1 | 1.28-1 | 2.04-1 | 1.02-1 |
| 0.08 | 6.19-1 | 2.95-1 | 2.15-1 | 1.22-1 | 1.86-1 | 9.30-2 |
| 0.16 | 6.63-1 | 3.15-1 | 1.89-1 | 1.11-1 | 1.56-1 | 7.77-2 |
| 0.32 | 7.30-1 | 3.44-1 | 1.52-1 | 9.63-2 | 1.11-1 | 5.53-2 |
| 0.64 | 8.01-1 | 3.76-1 | 1.11-1 | 7.96-2 | 6.16-2 | 3.06-2 |
| 1.28 | 8.33-1 | 3.89-1 | 7.73-2 | 6.51-2 | 2.34-2 | 1.14-2 |
| 2.56 | 7.47-1 | 3.49-1 | 5.52-2 | 5.18-2 | 5.92-3 | 2.72-3 |
| 5.12 | 5.96-1 | 2.78-1 | 4.12-2 | 4.00-2 | 1.69-3 | 6.57-4 |
| 10.24 | 4.31-1 | 2.01-1 | 2.92-2 | 2.87-2 | 5.77-4 | 1.51-4 |

| Z_S/Z_N | 14/16 | 14/16 | 14/16 | 14/16 | 14/16 | 14/16 |
|-----------|--------|--------|--------|--------|--------|--------|
| u | q | r | s | t | u | v |
| 0.01 | 6.50-1 | 3.06-1 | 2.61-1 | 1.51-1 | 2.39-1 | 1.19-1 |
| 0.02 | 6.55-1 | 3.07-1 | 2.55-1 | 1.48-1 | 2.33-1 | 1.16-1 |
| 0.04 | 6.73-1 | 3.15-1 | 2.46-1 | 1.45-1 | 2.22-1 | 1.11-1 |
| 0.08 | 7.01-1 | 3.26-1 | 2.27-1 | 1.38-1 | 2.01-1 | 1.00-1 |
| 0.16 | 7.50-1 | 3.47-1 | 1.98-1 | 1.28-1 | 1.67-1 | 8.32-2 |
| 0.32 | 8.18-1 | 3.76-1 | 1.55-1 | 1.12-1 | 1.18-1 | 5.88-2 |
| 0.64 | 8.95-1 | 4.08-1 | 1.08-1 | 9.52-2 | 6.47-2 | 3.18-2 |
| 1.28 | 9.13-1 | 4.14-1 | 7.16-2 | 7.97-2 | 2.50-2 | 1.19-2 |
| 2.56 | 8.15-1 | 3.69-1 | 4.93-2 | 6.46-2 | 6.95-3 | 2.90-3 |
| 5.12 | 6.47-1 | 2.93-1 | 3.63-2 | 5.00-2 | 2.53-3 | 8.06-4 |
| 10.24 | 4.65-1 | 2.10-1 | 2.55-2 | 3.57-2 | 1.17-3 | 2.59-4 |

Table 4. (continued)

| Z_S/Z_N | 18/20 | 18/20 | 18/20 | 18/20 | 18/20 | 18/20 |
|-----------|--------|--------|--------|--------|--------|--------|
| u | q | r | s | t | u | v |
| 0.01 | 7.70-1 | 3.38-1 | 2.77-1 | 1.86-1 | 2.67-1 | 1.32-1 |
| 0.02 | 7.81-1 | 3.42-1 | 2.71-1 | 1.85-1 | 2.61-1 | 1.29-1 |
| 0.04 | 7.99-1 | 3.48-1 | 2.59-1 | 1.82-1 | 2.48-1 | 1.23-1 |
| 0.08 | 8.34-1 | 3.60-1 | 2.37-1 | 1.76-1 | 2.25-1 | 1.11-1 |
| 0.16 | 8.89-1 | 3.79-1 | 2.00-1 | 1.67-1 | 1.86-1 | 9.12-2 |
| 0.32 | 9.73-1 | 4.08-1 | 1.48-1 | 1.54-1 | 1.32-1 | 6.39-2 |
| 0.64 | 1.05+0 | 4.34-1 | 9.28-2 | 1.39-1 | 7.40-2 | 3.44-2 |
| 1.28 | 1.06+0 | 4.34-1 | 5.18-2 | 1.23-1 | 3.19-2 | 1.33-2 |
| 2.56 | 9.30-1 | 3.80-1 | 3.03-2 | 1.02-1 | 1.26-2 | 3.87-3 |
| 5.12 | 7.30-1 | 2.98-1 | 2.09-2 | 7.91-2 | 6.89-3 | 1.55-3 |
| 10.24 | 5.22-1 | 2.13-1 | 1.43-2 | 5.63-2 | 4.30-3 | 7.90-4 |

| Z_S/Z_N | 20/22 | 20/22 | 20/22 | 20/22 | 20/22 | 20/22 |
|-----------|--------|--------|--------|--------|--------|--------|
| u | q | r | s | t | u | v |
| 0.01 | 8.19-1 | 3.45-1 | 2.81-1 | 2.07-1 | 2.81-1 | 1.38-1 |
| 0.02 | 8.32-1 | 3.49-1 | 2.74-1 | 2.06-1 | 2.73-1 | 1.34-1 |
| 0.04 | 8.51-1 | 3.55-1 | 2.61-1 | 2.03-1 | 2.60-1 | 1.27-1 |
| 0.08 | 8.86-1 | 3.65-1 | 2.37-1 | 1.98-1 | 2.36-1 | 1.15-1 |
| 0.16 | 9.43-1 | 3.82-1 | 1.97-1 | 1.90-1 | 1.96-1 | 9.44-2 |
| 0.32 | 1.02+0 | 4.05-1 | 1.41-1 | 1.79-1 | 1.40-1 | 6.59-2 |
| 0.64 | 1.10+0 | 4.27-1 | 8.28-2 | 1.66-1 | 8.09-2 | 3.58-2 |
| 1.28 | 1.11+0 | 4.26-1 | 4.08-2 | 1.51-1 | 3.88-2 | 1.45-2 |
| 2.56 | 9.77-1 | 3.73-1 | 2.02-2 | 1.27-1 | 1.84-2 | 4.78-3 |
| 5.12 | 7.62-1 | 2.91-1 | 1.28-2 | 9.82-2 | 1.14-2 | 2.25-3 |
| 10.24 | 5.42-1 | 2.07-1 | 8.51-3 | 6.97-2 | 7.52-3 | 1.29-3 |

| Z_S/Z_N | 24/26 | 24/26 | 24/26 | 24/26 | 24/26 | 24/26 |
|-----------|--------|--------|--------|--------|--------|--------|
| u | q | r | s | t | u | v |
| 0.01 | 8.87-1 | 3.42-1 | 2.87-1 | 2.52-1 | 3.07-1 | 1.47-1 |
| 0.02 | 8.94-1 | 3.42-1 | 2.78-1 | 2.51-1 | 2.99-1 | 1.42-1 |
| 0.04 | 9.17-1 | 3.48-1 | 2.64-1 | 2.51-1 | 2.86-1 | 1.36-1 |
| 0.08 | 9.54-1 | 3.55-1 | 2.38-1 | 2.49-1 | 2.61-1 | 1.23-1 |
| 0.16 | 1.01+0 | 3.67-1 | 1.93-1 | 2.45-1 | 2.20-1 | 1.01-1 |
| 0.32 | 1.10+0 | 3.85-1 | 1.33-1 | 2.41-1 | 1.64-1 | 7.10-2 |
| 0.64 | 1.17+0 | 3.98-1 | 6.97-2 | 2.34-1 | 1.05-1 | 3.99-2 |
| 1.28 | 1.17+0 | 3.91-1 | 2.55-2 | 2.20-1 | 6.23-2 | 1.79-2 |
| 2.56 | 1.01+0 | 3.36-1 | 6.61-3 | 1.86-1 | 3.88-2 | 7.81-3 |
| 5.12 | 7.93-1 | 2.62-1 | 2.17-3 | 1.44-1 | 2.74-2 | 4.61-3 |
| 10.24 | 5.64-1 | 1.86-1 | 9.27-4 | 1.02-1 | 1.89-2 | 2.98-3 |

Table 4. (continued)

| Z_S/Z_N | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 |
|-----------|--------|--------|--------|--------|--------|--------|
| u | q | r | s | t | u | v |
| 0.01 | 9.16-1 | 3.07-1 | 3.08-1 | 3.30-1 | 3.75-1 | 1.62-1 |
| 0.02 | 9.25-1 | 3.07-1 | 2.99-1 | 3.30-1 | 3.68-1 | 1.57-1 |
| 0.04 | 9.43-1 | 3.08-1 | 2.84-1 | 3.32-1 | 3.55-1 | 1.50-1 |
| 0.08 | 9.78-1 | 3.10-1 | 2.56-1 | 3.35-1 | 3.34-1 | 1.37-1 |
| 0.16 | 1.03+0 | 3.11-1 | 2.11-1 | 3.41-1 | 2.97-1 | 1.14-1 |
| 0.32 | 1.10+0 | 3.14-1 | 1.50-1 | 3.50-1 | 2.49-1 | 8.40-2 |
| 0.64 | 1.17+0 | 3.14-1 | 8.59-2 | 3.56-1 | 1.98-1 | 5.31-2 |
| 1.28 | 1.15+0 | 2.99-1 | 4.17-2 | 3.42-1 | 1.56-1 | 3.09-2 |
| 2.56 | 9.93-1 | 2.54-1 | 2.08-2 | 2.91-1 | 1.21-1 | 1.90-2 |
| 5.12 | 7.69-1 | 1.96-1 | 1.32-2 | 2.25-1 | 9.08-2 | 1.33-2 |
| 10.24 | 5.46-1 | 1.39-1 | 8.83-3 | 1.60-1 | 6.40-2 | 9.14-3 |

| Z_S/Z_N | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 |
|-----------|--------|--------|--------|--------|--------|--------|
| u | q | r | s | t | u | v |
| 0.01 | 9.06-1 | 2.99-1 | 3.14-1 | 3.42-1 | 3.93-1 | 1.65-1 |
| 0.02 | 9.18-1 | 3.00-1 | 3.06-1 | 3.44-1 | 3.87-1 | 1.61-1 |
| 0.04 | 9.32-1 | 2.99-1 | 2.91-1 | 3.45-1 | 3.75-1 | 1.53-1 |
| 0.08 | 9.63-1 | 2.99-1 | 2.63-1 | 3.50-1 | 3.54-1 | 1.40-1 |
| 0.16 | 1.01+0 | 2.99-1 | 2.19-1 | 3.58-1 | 3.21-1 | 1.18-1 |
| 0.32 | 1.08+0 | 2.99-1 | 1.59-1 | 3.69-1 | 2.76-1 | 8.80-2 |
| 0.64 | 1.14+0 | 2.97-1 | 9.64-2 | 3.75-1 | 2.27-1 | 5.72-2 |
| 1.28 | 1.12+0 | 2.80-1 | 5.23-2 | 3.61-1 | 1.85-1 | 3.49-2 |
| 2.56 | 9.75-1 | 2.39-1 | 3.02-2 | 3.10-1 | 1.47-1 | 2.26-2 |
| 5.12 | 7.51-1 | 1.83-1 | 2.05-2 | 2.39-1 | 1.11-1 | 1.60-2 |
| 10.24 | 5.32-1 | 1.30-1 | 1.40-2 | 1.69-1 | 7.81-2 | 1.11-2 |

| Z_S/Z_N | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 |
|-----------|--------|--------|--------|--------|--------|--------|
| u | q | r | s | t | u | v |
| 0.01 | 8.66-1 | 2.81-1 | 3.34-1 | 3.66-1 | 4.44-1 | 1.74-1 |
| 0.02 | 8.75-1 | 2.81-1 | 3.27-1 | 3.68-1 | 4.40-1 | 1.71-1 |
| 0.04 | 8.85-1 | 2.78-1 | 3.12-1 | 3.73-1 | 4.29-1 | 1.63-1 |
| 0.08 | 9.10-1 | 2.76-1 | 2.86-1 | 3.78-1 | 4.13-1 | 1.50-1 |
| 0.16 | 9.54-1 | 2.72-1 | 2.45-1 | 3.90-1 | 3.86-1 | 1.29-1 |
| 0.32 | 1.01+0 | 2.67-1 | 1.88-1 | 4.04-1 | 3.49-1 | 9.97-2 |
| 0.64 | 1.05+0 | 2.59-1 | 1.30-1 | 4.16-1 | 3.09-1 | 6.99-2 |
| 1.28 | 1.03+0 | 2.40-1 | 8.67-2 | 4.01-1 | 2.68-1 | 4.78-2 |
| 2.56 | 8.90-1 | 2.04-1 | 6.07-2 | 3.45-1 | 2.20-1 | 3.41-2 |
| 5.12 | 6.85-1 | 1.56-1 | 4.42-2 | 2.65-1 | 1.67-1 | 2.48-2 |
| 10.24 | 4.85-1 | 1.10-1 | 3.08-2 | 1.88-1 | 1.18-1 | 1.73-2 |

Table 5. Cross section of 1s-2s excitation (σ_C) for emission lines $1s^22p-1s2s^2$,
 $1s^22p-1s2p^2$ of Li-like ions: $\sigma = \sigma_C \times \frac{a_0^2}{Z_S^4}$ (cm^2), $E = 13.6 Z_S^2 (\Delta\epsilon + u)$ (ev)

Designations: **o**= $2s^21s\ ^2S_{1/2} - 1s^22p\ ^2P_{3/2}$, **p**= $2s^21s\ ^2S_{1/2} - 1s^22p\ ^2P_{1/2}$,
m= $2p^21s\ ^2S_{1/2} - 1s^22p\ ^2P_{3/2}$, **n**= $2p^21s\ ^2S_{1/2} - 1s^22p\ ^2P_{1/2}$, **c**= $2p^21s\ ^2P_{1/2} - 1s^22p\ ^2P_{3/2}$,
d= $2p^21s\ ^2P_{1/2} - 1s^22p\ ^2P_{1/2}$, **h**= $2p^21s\ ^4P_{1/2} - 1s^22p\ ^2P_{3/2}$, **i**= $2p^21s\ ^4P_{1/2} - 1s^22p\ ^2P_{1/2}$

| Z_S/Z_N | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 |
|-----------|----------|----------|----------|----------|----------|----------|----------|----------|
| U | o | p | m | n | c | d | h | i |
| 0.01 | 1.23-5 | 6.19-6 | 1.75-4 | 8.58-5 | 6.22-8 | 1.25-7 | 4.12-11 | 2.89-8 |
| 0.02 | 1.23-5 | 6.17-6 | 1.64-4 | 8.03-5 | 5.82-8 | 1.17-7 | 3.92-11 | 2.75-8 |
| 0.04 | 1.21-5 | 6.09-6 | 1.49-4 | 7.30-5 | 5.29-8 | 1.07-7 | 3.61-11 | 2.53-8 |
| 0.08 | 1.18-5 | 5.91-6 | 1.39-4 | 6.82-5 | 4.94-8 | 9.95-8 | 3.38-11 | 2.37-8 |
| 0.16 | 1.13-5 | 5.66-6 | 1.12-4 | 5.49-5 | 3.98-8 | 8.01-8 | 2.77-11 | 1.94-8 |
| 0.32 | 1.03-5 | 5.20-6 | 8.67-5 | 4.24-5 | 3.07-8 | 6.19-8 | 2.25-11 | 1.58-8 |
| 0.64 | 8.97-6 | 4.51-6 | 5.96-5 | 2.91-5 | 2.11-8 | 4.25-8 | 1.56-11 | 1.09-8 |
| 1.28 | 7.22-6 | 3.63-6 | 4.51-5 | 2.21-5 | 1.60-8 | 3.22-8 | 1.12-11 | 7.83-9 |
| 2.56 | 4.94-6 | 2.48-6 | 1.86-5 | 9.12-6 | 6.61-9 | 1.33-8 | 6.04-12 | 4.23-9 |
| 5.12 | 3.21-6 | 1.61-6 | 1.13-5 | 5.50-6 | 3.99-9 | 8.03-9 | 3.60-12 | 2.52-9 |
| 10.24 | 1.89-6 | 9.52-7 | 5.85-6 | 2.86-6 | 2.07-9 | 4.17-9 | 2.02-12 | 1.41-9 |

| Z_S/Z_N | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 |
|-----------|----------|----------|----------|----------|----------|----------|----------|----------|
| U | o | p | m | n | c | d | h | i |
| 0.01 | 3.24-5 | 1.64-5 | 4.06-4 | 1.97-4 | 1.80-7 | 3.63-7 | 1.45-9 | 1.84-7 |
| 0.02 | 3.24-5 | 1.64-5 | 3.78-4 | 1.83-4 | 1.68-7 | 3.38-7 | 1.35-9 | 1.72-7 |
| 0.04 | 3.19-5 | 1.61-5 | 3.70-4 | 1.79-4 | 1.64-7 | 3.31-7 | 1.30-9 | 1.66-7 |
| 0.08 | 3.12-5 | 1.58-5 | 3.21-4 | 1.56-4 | 1.42-7 | 2.87-7 | 1.16-9 | 1.47-7 |
| 0.16 | 3.00-5 | 1.51-5 | 2.84-4 | 1.38-4 | 1.26-7 | 2.54-7 | 1.06-9 | 1.35-7 |
| 0.32 | 2.77-5 | 1.40-5 | 2.34-4 | 1.13-4 | 1.03-7 | 2.09-7 | 8.73-10 | 1.11-7 |
| 0.64 | 2.41-5 | 1.22-5 | 1.48-4 | 7.19-5 | 6.57-8 | 1.33-7 | 6.20-10 | 7.89-8 |
| 1.28 | 1.88-5 | 9.49-6 | 1.05-4 | 5.10-5 | 4.66-8 | 9.40-8 | 4.23-10 | 5.38-8 |
| 2.56 | 1.27-5 | 6.41-6 | 5.34-5 | 2.59-5 | 2.37-8 | 4.77-8 | 2.57-10 | 3.28-8 |
| 5.12 | 8.02-6 | 4.05-6 | 3.44-5 | 1.67-5 | 1.52-8 | 3.07-8 | 1.60-10 | 2.04-8 |
| 10.24 | 4.65-6 | 2.35-6 | 1.70-5 | 8.23-6 | 7.52-9 | 1.52-8 | 8.67-11 | 1.10-8 |

Table 5 (continued)

| Z_S/Z_N | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 |
|-----------|--------|--------|--------|--------|--------|--------|--------|--------|
| U | o | p | m | n | c | d | h | i |
| 0.01 | 7.35-5 | 3.73-5 | 8.32-4 | 3.91-4 | 6.76-7 | 1.37-6 | 8.56-9 | 5.86-7 |
| 0.02 | 7.30-5 | 3.70-5 | 7.63-4 | 3.59-4 | 6.21-7 | 1.26-6 | 8.49-9 | 5.82-7 |
| 0.04 | 7.24-5 | 3.68-5 | 7.48-4 | 3.52-4 | 6.08-7 | 1.24-6 | 8.43-9 | 5.77-7 |
| 0.08 | 7.03-5 | 3.57-5 | 6.59-4 | 3.10-4 | 5.36-7 | 1.09-6 | 8.18-9 | 5.61-7 |
| 0.16 | 6.74-5 | 3.42-5 | 5.72-4 | 2.69-4 | 4.65-7 | 9.45-7 | 7.84-9 | 5.37-7 |
| 0.32 | 6.20-5 | 3.15-5 | 4.82-4 | 2.27-4 | 3.92-7 | 7.96-7 | 7.22-9 | 4.94-7 |
| 0.64 | 5.31-5 | 2.69-5 | 3.11-4 | 1.46-4 | 2.53-7 | 5.14-7 | 6.17-9 | 4.23-7 |
| 1.28 | 4.11-5 | 2.09-5 | 2.38-4 | 1.12-4 | 1.93-7 | 3.93-7 | 4.78-9 | 3.28-7 |
| 2.56 | 2.75-5 | 1.40-5 | 1.25-4 | 5.89-5 | 1.02-7 | 2.07-7 | 3.20-9 | 2.19-7 |
| 5.12 | 1.71-5 | 8.65-6 | 7.28-5 | 3.43-5 | 5.92-8 | 1.20-7 | 1.98-9 | 1.36-7 |
| 10.24 | 9.68-6 | 4.91-6 | 4.01-5 | 1.89-5 | 3.26-8 | 6.63-8 | 1.13-9 | 7.71-8 |
| | | | | | | | | |
| Z_S/Z_N | 8/10 | 8/10 | 8/10 | 8/10 | 8/10 | 8/10 | 8/10 | 8/10 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 2.65-4 | 1.36-4 | 2.42-3 | 1.06-3 | 3.60-6 | 7.45-6 | 1.64-7 | 6.59-6 |
| 0.02 | 2.63-4 | 1.35-4 | 2.24-3 | 9.83-4 | 3.33-6 | 6.89-6 | 1.57-7 | 6.29-6 |
| 0.04 | 2.59-4 | 1.33-4 | 2.11-3 | 9.27-4 | 3.13-6 | 6.49-6 | 1.48-7 | 5.93-6 |
| 0.08 | 2.53-4 | 1.30-4 | 1.94-3 | 8.52-4 | 2.88-6 | 5.97-6 | 1.39-7 | 5.59-6 |
| 0.16 | 2.41-4 | 1.24-4 | 1.77-3 | 7.77-4 | 2.63-6 | 5.44-6 | 1.28-7 | 5.14-6 |
| 0.32 | 2.19-4 | 1.13-4 | 1.45-3 | 6.40-4 | 2.16-6 | 4.48-6 | 1.08-7 | 4.33-6 |
| 0.64 | 1.83-4 | 9.43-5 | 9.92-4 | 4.36-4 | 1.48-6 | 3.06-6 | 8.02-8 | 3.22-6 |
| 1.28 | 1.36-4 | 7.02-5 | 7.25-4 | 3.19-4 | 1.08-6 | 2.24-6 | 5.80-8 | 2.32-6 |
| 2.56 | 9.01-5 | 4.64-5 | 4.27-4 | 1.88-4 | 6.35-7 | 1.31-6 | 3.54-8 | 1.42-6 |
| 5.12 | 5.53-5 | 2.85-5 | 2.51-4 | 1.10-4 | 3.73-7 | 7.72-7 | 2.15-8 | 8.63-7 |
| 10.24 | 3.10-5 | 1.60-5 | 1.30-4 | 5.72-5 | 1.94-7 | 4.01-7 | 1.18-8 | 4.71-7 |
| | | | | | | | | |
| Z_S/Z_N | 10/12 | 10/12 | 10/12 | 10/12 | 10/12 | 10/12 | 10/12 | 10/12 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 6.94-4 | 3.71-4 | 5.16-3 | 1.90-3 | 1.28-5 | 2.74-5 | 9.11-7 | 2.96-5 |
| 0.02 | 6.89-4 | 3.69-4 | 4.87-3 | 1.80-3 | 1.21-5 | 2.59-5 | 8.69-7 | 2.83-5 |
| 0.04 | 6.80-4 | 3.64-4 | 4.73-3 | 1.74-3 | 1.18-5 | 2.51-5 | 8.39-7 | 2.73-5 |
| 0.08 | 6.60-4 | 3.53-4 | 4.24-3 | 1.56-3 | 1.05-5 | 2.25-5 | 7.73-7 | 2.52-5 |
| 0.16 | 6.24-4 | 3.33-4 | 3.68-3 | 1.36-3 | 9.16-6 | 1.96-5 | 6.95-7 | 2.26-5 |
| 0.32 | 5.60-4 | 2.99-4 | 3.07-3 | 1.13-3 | 7.63-6 | 1.63-5 | 5.94-7 | 1.93-5 |
| 0.64 | 4.64-4 | 2.48-4 | 2.42-3 | 8.91-4 | 6.01-6 | 1.28-5 | 4.68-7 | 1.52-5 |
| 1.28 | 3.42-4 | 1.83-4 | 1.54-3 | 5.67-4 | 3.83-6 | 8.18-6 | 3.17-7 | 1.03-5 |
| 2.56 | 2.26-4 | 1.21-4 | 9.43-4 | 3.47-4 | 2.34-6 | 5.01-6 | 1.96-7 | 6.39-6 |
| 5.12 | 1.35-4 | 7.21-5 | 5.59-4 | 2.06-4 | 1.39-6 | 2.97-6 | 1.21-7 | 3.93-6 |
| 10.24 | 7.54-5 | 4.03-5 | 3.01-4 | 1.11-4 | 7.49-7 | 1.60-6 | 6.61-8 | 2.15-6 |

Table 5 (continued)

| | | | | | | | | |
|-----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Z_S/Z_N | 11/13 | 11/13 | 11/13 | 11/13 | 11/13 | 11/13 | 11/13 | 11/13 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 1.04-3 | 5.68-4 | 6.83-3 | 2.53-3 | 2.15-5 | 4.68-5 | 1.70-6 | 5.34-5 |
| 0.02 | 1.03-3 | 5.64-4 | 6.47-3 | 2.40-3 | 2.04-5 | 4.44-5 | 1.64-6 | 5.17-5 |
| 0.04 | 1.01-3 | 5.54-4 | 6.10-3 | 2.26-3 | 1.92-5 | 4.19-5 | 1.56-6 | 4.91-5 |
| 0.08 | 9.83-4 | 5.38-4 | 5.66-3 | 2.10-3 | 1.78-5 | 3.88-5 | 1.47-6 | 4.64-5 |
| 0.16 | 9.24-4 | 5.06-4 | 5.16-3 | 1.91-3 | 1.62-5 | 3.54-5 | 1.35-6 | 4.26-5 |
| 0.32 | 8.33-4 | 4.56-4 | 4.31-3 | 1.60-3 | 1.36-5 | 2.96-5 | 1.14-6 | 3.59-5 |
| 0.64 | 6.84-4 | 3.74-4 | 3.14-3 | 1.16-3 | 9.89-6 | 2.15-5 | 8.69-7 | 2.73-5 |
| 1.28 | 5.05-4 | 2.76-4 | 2.12-3 | 7.85-4 | 6.67-6 | 1.45-5 | 6.09-7 | 1.91-5 |
| 2.56 | 3.29-4 | 1.80-4 | 1.31-3 | 4.87-4 | 4.14-6 | 9.01-6 | 3.92-7 | 1.23-5 |
| 5.12 | 1.97-4 | 1.08-4 | 7.71-4 | 2.86-4 | 2.43-6 | 5.29-6 | 2.30-7 | 7.23-6 |
| 10.24 | 1.09-4 | 5.97-5 | 4.15-4 | 1.54-4 | 1.31-6 | 2.85-6 | 1.27-7 | 4.00-6 |
| Z_S/Z_N | 12/14 | 12/14 | 12/14 | 12/14 | 12/14 | 12/14 | 12/14 | 12/14 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 1.49-3 | 8.26-4 | 8.52-3 | 2.91-3 | 3.34-5 | 7.45-5 | 2.89-6 | 9.00-5 |
| 0.02 | 1.47-3 | 8.18-4 | 8.37-3 | 2.86-3 | 3.28-5 | 7.32-5 | 2.85-6 | 8.90-5 |
| 0.04 | 1.45-3 | 8.07-4 | 7.80-3 | 2.67-3 | 3.06-5 | 6.82-5 | 2.70-6 | 8.41-5 |
| 0.08 | 1.40-3 | 7.80-4 | 7.34-3 | 2.51-3 | 2.88-5 | 6.42-5 | 2.56-6 | 7.98-5 |
| 0.16 | 1.32-3 | 7.34-4 | 6.56-3 | 2.24-3 | 2.57-5 | 5.74-5 | 2.31-6 | 7.20-5 |
| 0.32 | 1.19-3 | 6.59-4 | 5.44-3 | 1.86-3 | 2.13-5 | 4.75-5 | 1.94-6 | 6.05-5 |
| 0.64 | 9.65-4 | 5.36-4 | 3.96-3 | 1.35-3 | 1.55-5 | 3.46-5 | 1.49-6 | 4.64-5 |
| 1.28 | 7.04-4 | 3.91-4 | 2.81-3 | 9.59-4 | 1.10-5 | 2.45-5 | 1.07-6 | 3.34-5 |
| 2.56 | 4.64-4 | 2.58-4 | 1.69-3 | 5.79-4 | 6.64-6 | 1.48-5 | 6.81-7 | 2.12-5 |
| 5.12 | 2.76-4 | 1.53-4 | 1.01-3 | 3.44-4 | 3.94-6 | 8.79-6 | 4.01-7 | 1.25-5 |
| 10.24 | 1.53-4 | 8.48-5 | 5.40-4 | 1.85-4 | 2.12-6 | 4.72-6 | 2.19-7 | 6.83-6 |
| Z_S/Z_N | 14/16 | 14/16 | 14/16 | 14/16 | 14/16 | 14/16 | 14/16 | 14/16 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 2.76-3 | 1.62-3 | 1.25-2 | 3.50-3 | 7.42-5 | 1.75-4 | 6.86-6 | 2.30-4 |
| 0.02 | 2.73-3 | 1.60-3 | 1.22-2 | 3.39-3 | 7.20-5 | 1.70-4 | 6.68-6 | 2.24-4 |
| 0.04 | 2.69-3 | 1.58-3 | 1.17-2 | 3.27-3 | 6.94-5 | 1.64-4 | 6.49-6 | 2.18-4 |
| 0.08 | 2.60-3 | 1.53-3 | 1.08-2 | 3.00-3 | 6.37-5 | 1.50-4 | 6.01-6 | 2.02-4 |
| 0.16 | 2.43-3 | 1.43-3 | 9.35-3 | 2.61-3 | 5.53-5 | 1.30-4 | 5.35-6 | 1.79-4 |
| 0.32 | 2.16-3 | 1.27-3 | 7.79-3 | 2.17-3 | 4.61-5 | 1.09-4 | 4.54-6 | 1.52-4 |
| 0.64 | 1.76-3 | 1.04-3 | 6.07-3 | 1.69-3 | 3.60-5 | 8.47-5 | 3.60-6 | 1.21-4 |
| 1.28 | 1.27-3 | 7.47-4 | 4.33-3 | 1.21-3 | 2.56-5 | 6.04-5 | 2.55-6 | 8.55-5 |
| 2.56 | 8.27-4 | 4.87-4 | 2.59-3 | 7.22-4 | 1.53-5 | 3.61-5 | 1.60-6 | 5.38-5 |
| 5.12 | 4.93-4 | 2.90-4 | 1.54-3 | 4.29-4 | 9.11-6 | 2.15-5 | 9.38-7 | 3.15-5 |
| 10.24 | 2.73-4 | 1.61-4 | 8.25-4 | 2.30-4 | 4.89-6 | 1.15-5 | 5.17-7 | 1.73-5 |

Table 5 (continued)

| | | | | | | | | |
|-----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Z_S/Z_N | 18/20 | 18/20 | 18/20 | 18/20 | 18/20 | 18/20 | 18/20 | 18/20 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 7.04-3 | 4.85-3 | 1.87-2 | 2.94-3 | 2.19-4 | 5.90-4 | 1.87-5 | 9.57-4 |
| 0.02 | 6.97-3 | 4.80-3 | 1.82-2 | 2.86-3 | 2.13-4 | 5.74-4 | 1.82-5 | 9.33-4 |
| 0.04 | 6.84-3 | 4.71-3 | 1.72-2 | 2.71-3 | 2.02-4 | 5.44-4 | 1.74-5 | 8.91-4 |
| 0.08 | 6.59-3 | 4.53-3 | 1.62-2 | 2.54-3 | 1.89-4 | 5.10-4 | 1.64-5 | 8.40-4 |
| 0.16 | 6.16-3 | 4.24-3 | 1.46-2 | 2.30-3 | 1.71-4 | 4.61-4 | 1.50-5 | 7.68-4 |
| 0.32 | 5.42-3 | 3.73-3 | 1.24-2 | 1.96-3 | 1.46-4 | 3.92-4 | 1.28-5 | 6.56-4 |
| 0.64 | 4.39-3 | 3.02-3 | 9.55-3 | 1.50-3 | 1.12-4 | 3.01-4 | 9.95-6 | 5.10-4 |
| 1.28 | 3.15-3 | 2.17-3 | 6.46-3 | 1.02-3 | 7.58-5 | 2.04-4 | 6.94-6 | 3.56-4 |
| 2.56 | 2.02-3 | 1.39-3 | 4.13-3 | 6.49-4 | 4.84-5 | 1.30-4 | 4.35-6 | 2.23-4 |
| 5.12 | 1.21-3 | 8.35-4 | 2.40-3 | 3.77-4 | 2.81-5 | 7.57-5 | 2.59-6 | 1.33-4 |
| 10.24 | 6.65-4 | 4.58-4 | 1.28-3 | 2.01-4 | 1.50-5 | 4.03-5 | 1.40-6 | 7.18-5 |
| | | | | | | | | |
| Z_S/Z_N | 20/22 | 20/22 | 20/22 | 20/22 | 20/22 | 20/22 | 20/22 | 20/22 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 1.01-2 | 7.59-3 | 2.00-2 | 2.17-3 | 3.03-4 | 8.84-4 | 2.26-5 | 1.67-3 |
| 0.02 | 9.96-3 | 7.51-3 | 1.97-2 | 2.14-3 | 2.99-4 | 8.72-4 | 2.22-5 | 1.64-3 |
| 0.04 | 9.77-3 | 7.36-3 | 1.86-2 | 2.02-3 | 2.83-4 | 8.23-4 | 2.12-5 | 1.57-3 |
| 0.08 | 9.42-3 | 7.10-3 | 1.76-2 | 1.91-3 | 2.67-4 | 7.79-4 | 2.01-5 | 1.48-3 |
| 0.16 | 8.75-3 | 6.60-3 | 1.59-2 | 1.72-3 | 2.41-4 | 7.02-4 | 1.82-5 | 1.34-3 |
| 0.32 | 7.70-3 | 5.81-3 | 1.35-2 | 1.46-3 | 2.04-4 | 5.95-4 | 1.56-5 | 1.15-3 |
| 0.64 | 6.23-3 | 4.70-3 | 1.01-2 | 1.10-3 | 1.54-4 | 4.48-4 | 1.19-5 | 8.83-4 |
| 1.28 | 4.51-3 | 3.40-3 | 7.05-3 | 7.65-4 | 1.07-4 | 3.11-4 | 8.35-6 | 6.17-4 |
| 2.56 | 2.88-3 | 2.17-3 | 4.52-3 | 4.91-4 | 6.86-5 | 2.00-4 | 5.40-6 | 3.99-4 |
| 5.12 | 1.71-3 | 1.29-3 | 2.65-3 | 2.87-4 | 4.01-5 | 1.17-4 | 3.15-6 | 2.33-4 |
| 10.24 | 9.40-4 | 7.09-4 | 1.42-3 | 1.54-4 | 2.15-5 | 6.27-5 | 1.70-6 | 1.26-4 |
| | | | | | | | | |
| Z_S/Z_N | 24/26 | 24/26 | 24/26 | 24/26 | 24/26 | 24/26 | 24/26 | 24/26 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 1.71-2 | 1.65-2 | 1.97-2 | 8.84-4 | 4.21-4 | 1.40-3 | 1.80-5 | 4.06-3 |
| 0.02 | 1.70-2 | 1.63-2 | 1.93-2 | 8.66-4 | 4.13-4 | 1.37-3 | 1.76-5 | 3.97-3 |
| 0.04 | 1.66-2 | 1.60-2 | 1.86-2 | 8.34-4 | 3.97-4 | 1.32-3 | 1.69-5 | 3.83-3 |
| 0.08 | 1.60-2 | 1.54-2 | 1.75-2 | 7.84-4 | 3.74-4 | 1.24-3 | 1.60-5 | 3.61-3 |
| 0.16 | 1.48-2 | 1.43-2 | 1.56-2 | 6.99-4 | 3.33-4 | 1.10-3 | 1.43-5 | 3.23-3 |
| 0.32 | 1.30-2 | 1.25-2 | 1.32-2 | 5.95-4 | 2.83-4 | 9.39-4 | 1.22-5 | 2.75-3 |
| 0.64 | 1.04-2 | 1.00-2 | 1.01-2 | 4.52-4 | 2.15-4 | 7.14-4 | 9.37-6 | 2.12-3 |
| 1.28 | 7.47-3 | 7.19-3 | 7.09-3 | 3.18-4 | 1.52-4 | 5.03-4 | 6.58-6 | 1.49-3 |
| 2.56 | 4.79-3 | 4.61-3 | 4.46-3 | 2.01-4 | 9.56-5 | 3.17-4 | 4.17-6 | 9.43-4 |
| 5.12 | 2.86-3 | 2.75-3 | 2.64-3 | 1.19-4 | 5.65-5 | 1.87-4 | 2.47-6 | 5.57-4 |
| 10.24 | 1.57-3 | 1.51-3 | 1.43-3 | 6.44-5 | 3.07-5 | 1.02-4 | 1.35-6 | 3.04-4 |

Table 5 (continued)

| | | | | | | | | |
|-----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Z_S/Z_N | 26/28 | 26/28 | 26/28 | 26/28 | 26/28 | 26/28 | 26/28 | 26/28 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 2.08-2 | 2.31-2 | 1.83-2 | 5.03-4 | 4.29-4 | 1.48-3 | 1.09-5 | 5.72-3 |
| 0.02 | 2.06-2 | 2.29-2 | 1.78-2 | 4.90-4 | 4.18-4 | 1.44-3 | 1.07-5 | 5.58-3 |
| 0.04 | 2.01-2 | 2.24-2 | 1.73-2 | 4.75-4 | 4.06-4 | 1.40-3 | 1.04-5 | 5.42-3 |
| 0.08 | 1.94-2 | 2.15-2 | 1.61-2 | 4.44-4 | 3.79-4 | 1.31-3 | 9.70-6 | 5.07-3 |
| 0.16 | 1.80-2 | 2.00-2 | 1.45-2 | 3.99-4 | 3.40-4 | 1.17-3 | 8.69-6 | 4.54-3 |
| 0.32 | 1.57-2 | 1.75-2 | 1.22-2 | 3.36-4 | 2.87-4 | 9.90-4 | 7.37-6 | 3.85-3 |
| 0.64 | 1.26-2 | 1.41-2 | 9.38-3 | 2.58-4 | 2.20-4 | 7.60-4 | 5.67-6 | 2.96-3 |
| 1.28 | 9.08-3 | 1.01-2 | 6.61-3 | 1.82-4 | 1.55-4 | 5.35-4 | 3.99-6 | 2.09-3 |
| 2.56 | 5.84-3 | 6.50-3 | 4.11-3 | 1.13-4 | 9.65-5 | 3.33-4 | 2.51-6 | 1.31-3 |
| 5.12 | 3.43-3 | 3.81-3 | 2.49-3 | 6.84-5 | 5.84-5 | 2.01-4 | 1.51-6 | 7.90-4 |
| 10.24 | 1.89-3 | 2.10-3 | 1.34-3 | 3.69-5 | 3.15-5 | 1.09-4 | 8.17-7 | 4.27-4 |
| Z_S/Z_N | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 2.41-2 | 3.13-2 | 1.65-2 | 2.70-4 | 4.04-4 | 1.42-3 | 4.46-6 | 7.59-3 |
| 0.02 | 2.38-2 | 3.09-2 | 1.60-2 | 2.63-4 | 3.93-4 | 1.38-3 | 4.34-6 | 7.39-3 |
| 0.04 | 2.34-2 | 3.03-2 | 1.55-2 | 2.55-4 | 3.82-4 | 1.34-3 | 4.22-6 | 7.18-3 |
| 0.08 | 2.25-2 | 2.92-2 | 1.46-2 | 2.39-4 | 3.57-4 | 1.25-3 | 3.95-6 | 6.72-3 |
| 0.16 | 2.08-2 | 2.70-2 | 1.30-2 | 2.14-4 | 3.19-4 | 1.12-3 | 3.52-6 | 5.99-3 |
| 0.32 | 1.82-2 | 2.36-2 | 1.10-2 | 1.80-4 | 2.69-4 | 9.43-4 | 2.98-6 | 5.06-3 |
| 0.64 | 1.46-2 | 1.90-2 | 8.58-3 | 1.41-4 | 2.10-4 | 7.37-4 | 2.33-6 | 3.96-3 |
| 1.28 | 1.05-2 | 1.37-2 | 5.98-3 | 9.83-5 | 1.47-4 | 5.15-4 | 1.63-6 | 2.77-3 |
| 2.56 | 6.70-3 | 8.69-3 | 3.77-3 | 6.20-5 | 9.26-5 | 3.25-4 | 1.03-6 | 1.75-3 |
| 5.12 | 3.98-3 | 5.16-3 | 2.24-3 | 3.68-5 | 5.50-5 | 1.93-4 | 6.10-7 | 1.04-3 |
| 10.24 | 2.18-3 | 2.82-3 | 1.22-3 | 2.00-5 | 2.99-5 | 1.05-4 | 3.32-7 | 5.64-4 |
| Z_S/Z_N | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 2.71-2 | 4.15-2 | 1.15-2 | 1.11-4 | 3.53-4 | 1.23-3 | 7.07-7 | 9.49-3 |
| 0.02 | 2.68-2 | 4.11-2 | 1.11-2 | 1.08-4 | 3.43-4 | 1.19-3 | 6.86-7 | 9.21-3 |
| 0.04 | 2.63-2 | 4.03-2 | 1.09-2 | 1.05-4 | 3.34-4 | 1.16-3 | 6.69-7 | 8.98-3 |
| 0.08 | 2.52-2 | 3.86-2 | 1.01-2 | 9.80-5 | 3.12-4 | 1.09-3 | 6.23-7 | 8.36-3 |
| 0.16 | 2.34-2 | 3.59-2 | 9.04-3 | 8.76-5 | 2.79-4 | 9.71-4 | 5.58-7 | 7.49-3 |
| 0.32 | 2.05-2 | 3.14-2 | 7.68-3 | 7.44-5 | 2.37-4 | 8.24-4 | 4.74-7 | 6.36-3 |
| 0.64 | 1.64-2 | 2.51-2 | 5.99-3 | 5.80-5 | 1.84-4 | 6.42-4 | 3.69-7 | 4.95-3 |
| 1.28 | 1.18-2 | 1.81-2 | 4.21-3 | 4.08-5 | 1.30-4 | 4.52-4 | 2.60-7 | 3.49-3 |
| 2.56 | 7.54-3 | 1.16-2 | 2.68-3 | 2.59-5 | 8.23-5 | 2.87-4 | 1.64-7 | 2.21-3 |
| 5.12 | 4.45-3 | 6.82-3 | 1.57-3 | 1.52-5 | 4.85-5 | 1.69-4 | 9.69-8 | 1.30-3 |
| 10.24 | 2.44-3 | 3.74-3 | 8.54-4 | 8.28-6 | 2.63-5 | 9.16-5 | 5.26-8 | 7.06-4 |

Table 5 (continued)

| | | | | | | | | |
|-----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Z_S/Z_N | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 2.94-2 | 5.33-2 | 1.25-2 | 7.12-5 | 2.89-4 | 9.88-4 | 1.12-7 | 1.13-2 |
| 0.02 | 2.92-2 | 5.30-2 | 1.21-2 | 6.91-5 | 2.81-4 | 9.59-4 | 1.09-7 | 1.10-2 |
| 0.04 | 2.85-2 | 5.16-2 | 1.18-2 | 6.72-5 | 2.73-4 | 9.33-4 | 1.06-7 | 1.06-2 |
| 0.08 | 2.75-2 | 4.98-2 | 1.10-2 | 6.27-5 | 2.55-4 | 8.71-4 | 9.91-8 | 9.94-3 |
| 0.16 | 2.54-2 | 4.60-2 | 9.91-3 | 5.65-5 | 2.30-4 | 7.85-4 | 8.93-8 | 8.96-3 |
| 0.32 | 2.22-2 | 4.03-2 | 8.40-3 | 4.79-5 | 1.95-4 | 6.66-4 | 7.58-8 | 7.60-3 |
| 0.64 | 1.78-2 | 3.22-2 | 6.57-3 | 3.75-5 | 1.52-4 | 5.20-4 | 5.91-8 | 5.93-3 |
| 1.28 | 1.28-2 | 2.32-2 | 4.65-3 | 2.65-5 | 1.08-4 | 3.68-4 | 4.19-8 | 4.20-3 |
| 2.56 | 8.22-3 | 1.49-2 | 2.91-3 | 1.66-5 | 6.75-5 | 2.31-4 | 2.63-8 | 2.63-3 |
| 5.12 | 4.82-3 | 8.73-3 | 1.73-3 | 9.88-6 | 4.01-5 | 1.37-4 | 1.56-8 | 1.56-3 |
| 10.24 | 2.64-3 | 4.79-3 | 9.37-4 | 5.35-6 | 2.17-5 | 7.42-5 | 8.44-9 | 8.47-4 |
| Z_S/Z_N | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 |
| U | o | p | m | n | c | d | h | i |
| 0.010 | 3.11-2 | 6.70-2 | 9.57-3 | 3.25-5 | 2.26-4 | 7.44-4 | 1.71-6 | 1.29-2 |
| 0.020 | 3.06-2 | 6.61-2 | 9.30-3 | 3.15-5 | 2.19-4 | 7.23-4 | 1.66-6 | 1.25-2 |
| 0.040 | 3.01-2 | 6.49-2 | 9.05-3 | 3.07-5 | 2.13-4 | 7.04-4 | 1.62-6 | 1.22-2 |
| 0.080 | 2.89-2 | 6.23-2 | 8.47-3 | 2.87-5 | 2.00-4 | 6.59-4 | 1.51-6 | 1.14-2 |
| 0.160 | 2.68-2 | 5.78-2 | 7.64-3 | 2.59-5 | 1.80-4 | 5.94-4 | 1.37-6 | 1.03-2 |
| 0.320 | 2.33-2 | 5.03-2 | 6.49-3 | 2.20-5 | 1.53-4 | 5.05-4 | 1.16-6 | 8.73-3 |
| 0.640 | 1.86-2 | 4.02-2 | 5.07-3 | 1.72-5 | 1.20-4 | 3.94-4 | 9.06-7 | 6.82-3 |
| 1.280 | 1.34-2 | 2.90-2 | 3.60-3 | 1.22-5 | 8.49-5 | 2.80-4 | 6.43-7 | 4.84-3 |
| 2.560 | 8.71-3 | 1.88-2 | 2.25-3 | 7.62-6 | 5.29-5 | 1.75-4 | 4.01-7 | 3.02-3 |
| 5.120 | 5.09-3 | 1.10-2 | 1.33-3 | 4.52-6 | 3.14-5 | 1.04-4 | 2.38-7 | 1.79-3 |
| 10.240 | 2.79-3 | 6.02-3 | 7.26-4 | 2.46-6 | 1.71-5 | 5.64-5 | 1.30-7 | 9.75-4 |
| Z_S/Z_N | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 |
| U | o | p | m | n | c | d | h | i |
| 0.01 | 3.13-2 | 1.16-1 | 6.32-3 | 5.14-6 | 8.60-5 | 2.53-4 | 7.87-6 | 1.51-2 |
| 0.02 | 3.10-2 | 1.15-1 | 6.14-3 | 4.99-6 | 8.36-5 | 2.47-4 | 7.80-6 | 1.49-2 |
| 0.04 | 3.04-2 | 1.13-1 | 5.97-3 | 4.85-6 | 8.13-5 | 2.40-4 | 7.65-6 | 1.46-2 |
| 0.08 | 2.92-2 | 1.08-1 | 5.60-3 | 4.55-6 | 7.64-5 | 2.25-4 | 7.33-6 | 1.40-2 |
| 0.16 | 2.70-2 | 1.00-1 | 5.09-3 | 4.14-6 | 6.93-5 | 2.04-4 | 6.79-6 | 1.30-2 |
| 0.32 | 2.36-2 | 8.75-2 | 4.30-3 | 3.49-6 | 5.86-5 | 1.73-4 | 5.94-6 | 1.14-2 |
| 0.64 | 1.89-2 | 6.99-2 | 3.39-3 | 2.75-6 | 4.62-5 | 1.36-4 | 4.75-6 | 9.09-3 |
| 1.28 | 1.35-2 | 5.01-2 | 2.40-3 | 1.95-6 | 3.27-5 | 9.64-5 | 3.40-6 | 6.51-3 |
| 2.56 | 8.86-3 | 3.28-2 | 1.53-3 | 1.25-6 | 2.09-5 | 6.15-5 | 2.23-6 | 4.26-3 |
| 5.12 | 5.17-3 | 1.91-2 | 8.96-4 | 7.29-7 | 1.22-5 | 3.60-5 | 1.30-6 | 2.49-3 |
| 10.24 | 2.83-3 | 1.05-2 | 4.89-4 | 3.97-7 | 6.66-6 | 1.96-5 | 7.11-7 | 1.36-3 |

Table 6. Rate coefficients (R_C) for $1s^2 2s - 1s 2s 2p$ excitation of Li-like ions:

$$R = 10^{-8} \frac{R_C}{Z_S^3} \exp(-\beta \Delta \epsilon) \text{ in cm}^3/\text{s}$$

Designations: $q=2s2p(^3P)1s^2 P_{3/2} - 1s^2 2s^2 S_{1/2}$, $r=2s2p(^3P)1s^2 P_{1/2} - 1s^2 2s^2 S_{1/2}$,

$s=2s2p(^1P)1s^2 P_{3/2} - 1s^2 2s^2 S_{1/2}$, $t=2s2p(^1P)1s^2 P_{1/2} - 1s^2 2s^2 S_{1/2}$,

$u=2s2p(^3P)1s^4 P_{3/2} - 1s^2 2s^2 S_{1/2}$, $v=2s2p(^3P)1s^4 P_{1/2} - 1s^2 2s^2 S_{1/2}$,

| Z_S/Z_N | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 |
|-------------------|--------|--------|--------|--------|--------|--------|
| β | q | r | s | t | u | v |
| 0.25 | 1.16+0 | 5.75-1 | 1.30-1 | 7.05-2 | 2.72-2 | 1.36-2 |
| 0.5 | 1.14+0 | 5.65-1 | 1.56-1 | 8.36-2 | 5.81-2 | 2.91-2 |
| 1.0 | 1.11+0 | 5.54-1 | 2.03-1 | 1.07-1 | 1.12-1 | 5.60-2 |
| 2.0 | 1.12+0 | 5.59-1 | 2.78-1 | 1.44-1 | 1.94-1 | 9.68-2 |
| 4.0 | 1.22+0 | 6.07-1 | 3.85-1 | 1.97-1 | 3.03-1 | 1.51-1 |
| 8.0 | 1.45+0 | 7.21-1 | 5.32-1 | 2.71-1 | 4.41-1 | 2.20-1 |
| 16 | 1.81+0 | 9.02-1 | 7.18-1 | 3.65-1 | 6.09-1 | 3.05-1 |
| 32 | 2.25+0 | 1.12+0 | 9.27-1 | 4.71-1 | 7.96-1 | 3.98-1 |
| $\Delta \epsilon$ | 1.3777 | 1.3776 | 1.3940 | 1.3940 | 1.3518 | 1.3518 |

| Z_S/Z_N | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 |
|-------------------|--------|--------|--------|--------|--------|--------|
| β | q | r | s | t | u | v |
| 0.25 | 1.52+0 | 7.51-1 | 1.75-1 | 9.22-2 | 3.23-2 | 1.62-2 |
| 0.5 | 1.50+0 | 7.43-1 | 2.09-1 | 1.09-1 | 7.06-2 | 3.53-2 |
| 1.0 | 1.48+0 | 7.32-1 | 2.69-1 | 1.39-1 | 1.40-1 | 7.00-2 |
| 2.0 | 1.49+0 | 7.40-1 | 3.69-1 | 1.88-1 | 2.49-1 | 1.25-1 |
| 4.0 | 1.61+0 | 7.98-1 | 5.18-1 | 2.63-1 | 4.02-1 | 2.01-1 |
| 8.0 | 1.87+0 | 9.30-1 | 7.22-1 | 3.65-1 | 6.00-1 | 3.00-1 |
| 16 | 2.29+0 | 1.14+0 | 9.84-1 | 4.96-1 | 8.44-1 | 4.22-1 |
| 32 | 2.82+0 | 1.40+0 | 1.28+0 | 6.45-1 | 1.12+0 | 5.58-1 |
| $\Delta \epsilon$ | 1.2384 | 1.2383 | 1.2505 | 1.2505 | 1.2172 | 1.2172 |

| Z_S/Z_N | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 |
|-------------------|--------|--------|--------|--------|--------|--------|
| β | q | r | s | t | u | v |
| 0.25 | 1.84+0 | 9.10-1 | 2.05-1 | 1.12-1 | 3.58-2 | 1.79-2 |
| 0.5 | 1.84+0 | 9.11-1 | 2.45-1 | 1.32-1 | 7.93-2 | 3.96-2 |
| 1.0 | 1.83+0 | 9.05-1 | 3.16-1 | 1.67-1 | 1.60-1 | 8.00-2 |
| 2.0 | 1.85+0 | 9.14-1 | 4.36-1 | 2.26-1 | 2.90-1 | 1.45-1 |
| 4.0 | 1.98+0 | 9.79-1 | 6.17-1 | 3.17-1 | 4.77-1 | 2.39-1 |
| 8.0 | 2.28+0 | 1.13+0 | 8.69-1 | 4.43-1 | 7.23-1 | 3.62-1 |
| 16 | 2.77+0 | 1.38+0 | 1.19+0 | 6.05-1 | 1.03+0 | 5.14-1 |
| 32 | 3.39+0 | 1.68+0 | 1.55+0 | 7.87-1 | 1.36+0 | 6.82-1 |
| $\Delta \epsilon$ | 1.1495 | 1.1494 | 1.1591 | 1.1591 | 1.1396 | 1.1315 |

Table 6.(continued)

| Z_S/Z_N | 8/10 | 8/10 | 8/10 | 8/10 | 8/10 | 8/10 |
|---------------------|--------|--------|--------|--------|--------|--------|
| β | q | r | s | t | u | v |
| 0.25 | 2.35+0 | 1.14+0 | 2.43-1 | 1.47-1 | 4.06-2 | 2.02-2 |
| 0.5 | 2.38+0 | 1.16+0 | 2.92-1 | 1.71-1 | 9.09-2 | 4.54-2 |
| 1.0 | 2.39+0 | 1.16+0 | 3.80-1 | 2.14-1 | 1.87-1 | 9.32-2 |
| 2.0 | 2.44+0 | 1.19+0 | 5.29-1 | 2.88-1 | 3.46-1 | 1.73-1 |
| 4.0 | 2.62+0 | 1.28+0 | 7.58-1 | 4.01-1 | 5.79-1 | 2.90-1 |
| 8.0 | 3.01+0 | 1.48+0 | 1.08+0 | 5.62-1 | 8.92-1 | 4.46-1 |
| 16 | 3.64+0 | 1.79+0 | 1.49+0 | 7.70-1 | 1.28+0 | 6.41-1 |
| 32 | 4.43+0 | 2.18+0 | 1.95+0 | 1.01+0 | 1.71+0 | 8.56-1 |
| $\Delta\varepsilon$ | 1.0430 | 1.0428 | 1.0497 | 1.0497 | 1.0292 | 1.0291 |
| Z_S/Z_N | 10/12 | 10/12 | 10/12 | 10/12 | 10/12 | 10/12 |
| β | q | r | s | t | u | v |
| 0.25 | 2.74+0 | 1.31+0 | 2.55-1 | 1.82-1 | 4.36-2 | 2.15-2 |
| 0.5 | 2.80+0 | 1.34+0 | 3.10-1 | 2.09-1 | 9.76-2 | 4.84-2 |
| 1.0 | 2.83+0 | 1.36+0 | 4.08-1 | 2.57-1 | 2.02-1 | 1.00-1 |
| 2.0 | 2.91+0 | 1.40+0 | 5.77-1 | 3.39-1 | 3.78-1 | 1.89-1 |
| 4.0 | 3.14+0 | 1.52+0 | 8.38-1 | 4.69-1 | 6.42-1 | 3.20-1 |
| 8.0 | 3.62+0 | 1.75+0 | 1.20+0 | 6.55-1 | 9.99-1 | 4.99-1 |
| 16 | 4.37+0 | 2.12+0 | 1.68+0 | 8.96-1 | 1.45+0 | 7.23-1 |
| 32 | 5.31+0 | 2.58+0 | 2.21+0 | 1.17+0 | 1.94+0 | 9.71-1 |
| $\Delta\varepsilon$ | 0.9816 | 0.9814 | 0.9868 | 0.9867 | 0.9703 | 0.9702 |
| Z_S/Z_N | 11/13 | 11/13 | 11/13 | 11/13 | 11/13 | 11/13 |
| β | q | r | s | t | u | v |
| 0.25 | 2.90+0 | 1.38+0 | 2.54-1 | 2.01-1 | 4.53-2 | 2.20-2 |
| 0.5 | 2.97+0 | 1.41+0 | 3.11-1 | 2.30-1 | 1.01-1 | 4.97-2 |
| 1.0 | 3.02+0 | 1.44+0 | 4.13-1 | 2.80-1 | 2.08-1 | 1.03-1 |
| 2.0 | 3.11+0 | 1.49+0 | 5.89-1 | 3.65-1 | 3.90-1 | 1.94-1 |
| 4.0 | 3.36+0 | 1.61+0 | 8.61-1 | 5.00-1 | 6.64-1 | 3.32-1 |
| 8.0 | 3.86+0 | 1.86+0 | 1.24+0 | 6.96-1 | 1.04+0 | 5.18-1 |
| 16 | 4.67+0 | 2.25+0 | 1.74+0 | 9.51-1 | 1.51+0 | 7.53-1 |
| 32 | 5.67+0 | 2.74+0 | 2.29+0 | 1.24+0 | 2.03+0 | 1.01+0 |
| $\Delta\varepsilon$ | 0.9598 | 0.9595 | 0.9644 | 0.9643 | 0.9495 | 0.9493 |

Table 6.(continued)

| | | | | | | |
|---------------------|--------|--------|--------|--------|--------|--------|
| Z_S/Z_N | 12/14 | 12/14 | 12/14 | 12/14 | 12/14 | 12/14 |
| β | q | r | s | t | u | v |
| 0.25 | 3.05+0 | 1.43+0 | 2.47-1 | 2.22-1 | 4.72-2 | 2.26-2 |
| 0.5 | 3.14+0 | 1.47+0 | 3.06-1 | 2.52-1 | 1.04-1 | 5.09-2 |
| 1.0 | 3.20+0 | 1.50+0 | 4.12-1 | 3.04-1 | 2.14-1 | 1.06-1 |
| 2.0 | 3.30+0 | 1.55+0 | 5.94-1 | 3.92-1 | 4.01-1 | 2.00-1 |
| 4.0 | 3.57+0 | 1.69+0 | 8.76-1 | 5.32-1 | 6.84-1 | 3.41-1 |
| 8.0 | 4.10+0 | 1.95+0 | 1.27+0 | 7.35-1 | 1.07+0 | 5.34-1 |
| 16 | 4.96+0 | 2.36+0 | 1.78+0 | 1.00+0 | 1.56+0 | 7.77-1 |
| 32 | 6.02+0 | 2.88+0 | 2.36+0 | 1.31+0 | 2.09+0 | 1.05+0 |
| $\Delta\varepsilon$ | 0.9419 | 0.9416 | 0.9461 | 0.9460 | 0.9323 | 0.9318 |
| Z_S/Z_N | 14/16 | 14/16 | 14/16 | 14/16 | 14/16 | 14/16 |
| β | q | r | s | t | u | v |
| 0.25 | 3.30+0 | 1.50+0 | 2.23-1 | 2.72-1 | 5.24-2 | 2.38-2 |
| 0.5 | 3.40+0 | 1.54+0 | 2.83-1 | 3.04-1 | 1.11-1 | 5.29-2 |
| 1.0 | 3.48+0 | 1.59+0 | 3.95-1 | 3.59-1 | 2.24-1 | 1.10-1 |
| 2.0 | 3.61+0 | 1.65+0 | 5.87-1 | 4.51-1 | 4.20-1 | 2.08-1 |
| 4.0 | 3.91+0 | 1.80+0 | 8.85-1 | 6.00-1 | 7.17-1 | 3.56-1 |
| 8.0 | 4.51+0 | 2.10+0 | 1.30+0 | 8.19-1 | 1.13+0 | 5.60-1 |
| 16 | 5.45+0 | 2.55+0 | 1.84+0 | 1.11+0 | 1.64+0 | 8.17-1 |
| 32 | 6.63+0 | 3.10+0 | 2.44+0 | 1.44+0 | 2.21+0 | 1.10+0 |
| $\Delta\varepsilon$ | 0.9142 | 0.9139 | 0.9178 | 0.9177 | 0.9059 | 0.9057 |
| Z_S/Z_N | 18/20 | 18/20 | 18/20 | 18/20 | 18/20 | 18/20 |
| β | q | r | s | t | u | v |
| 0.25 | 3.72+0 | 1.52+0 | 1.46-1 | 4.19-1 | 7.56-2 | 2.83-2 |
| 0.5 | 3.85+0 | 1.58+0 | 2.09-1 | 4.57-1 | 1.36-1 | 5.87-2 |
| 1.0 | 3.97+0 | 1.64+0 | 3.27-1 | 5.16-1 | 2.55-1 | 1.18-1 |
| 2.0 | 4.13+0 | 1.73+0 | 5.32-1 | 6.14-1 | 4.60-1 | 2.21-1 |
| 4.0 | 4.49+0 | 1.90+0 | 8.48-1 | 7.76-1 | 7.76-1 | 3.78-1 |
| 8.0 | 5.17+0 | 2.22+0 | 1.29+0 | 1.02+0 | 1.21+0 | 5.96-1 |
| 16 | 6.24+0 | 2.70+0 | 1.85+0 | 1.35+0 | 1.77+0 | 8.71-1 |
| 32 | 7.57+0 | 3.30+0 | 2.48+0 | 1.73+0 | 2.38+0 | 1.18+0 |
| $\Delta\varepsilon$ | 0.8788 | 0.8782 | 0.8815 | 0.8813 | 0.8719 | 0.8696 |

Table 6.(continued)

| | | | | | | |
|---------------------|--------|--------|--------|--------|--------|--------|
| Z_S/Z_N | 20/22 | 20/22 | 20/22 | 20/22 | 20/22 | 20/22 |
| β | q | r | s | t | u | v |
| 0.25 | 3.87+0 | 1.48+0 | 1.06-1 | 5.15-1 | 9.88-2 | 3.21-2 |
| 0.5 | 4.02+0 | 1.55+0 | 1.68-1 | 5.56-1 | 1.61-1 | 6.29-2 |
| 1.0 | 4.14+0 | 1.61+0 | 2.88-1 | 6.16-1 | 2.81-1 | 1.23-1 |
| 2.0 | 4.31+0 | 1.70+0 | 4.96-1 | 7.16-1 | 4.89-1 | 2.27-1 |
| 4.0 | 4.69+0 | 1.88+0 | 8.17-1 | 8.83-1 | 8.10-1 | 3.87-1 |
| 8.0 | 5.41+0 | 2.21+0 | 1.27+0 | 1.14+0 | 1.26+0 | 6.10-1 |
| 16 | 6.55+0 | 2.71+0 | 1.83+0 | 1.50+0 | 1.83+0 | 8.92-1 |
| 32 | 7.95+0 | 3.32+0 | 2.47+0 | 1.91+0 | 2.46+0 | 1.21+0 |
| $\Delta\varepsilon$ | 0.8669 | 0.8662 | 0.8694 | 0.8691 | 0.8606 | 0.8602 |
| Z_S/Z_N | 24/26 | 24/26 | 24/26 | 24/26 | 24/26 | 24/26 |
| β | q | r | s | t | u | v |
| 0.25 | 4.03+0 | 1.34+0 | 5.27-2 | 7.45-1 | 1.80-1 | 4.41-2 |
| 0.5 | 4.19+0 | 1.40+0 | 1.14-1 | 7.94-1 | 2.45-1 | 7.55-2 |
| 1.0 | 4.33+0 | 1.47+0 | 2.36-1 | 8.60-1 | 3.68-1 | 1.37-1 |
| 2.0 | 4.54+0 | 1.57+0 | 4.49-1 | 9.65-1 | 5.81-1 | 2.43-1 |
| 4.0 | 4.95+0 | 1.77+0 | 7.78-1 | 1.14+0 | 9.13-1 | 4.09-1 |
| 8.0 | 5.72+0 | 2.10+0 | 1.23+0 | 1.43+0 | 1.38+0 | 6.39-1 |
| 16 | 6.92+0 | 2.59+0 | 1.81+0 | 1.83+0 | 1.98+0 | 9.32-1 |
| 32 | 8.41+0 | 3.19+0 | 2.45+0 | 2.31+0 | 2.65+0 | 1.26+0 |
| $\Delta\varepsilon$ | 0.8501 | 0.8490 | 0.8523 | 0.8519 | 0.8443 | 0.8439 |
| Z_S/Z_N | 26/28 | 26/28 | 26/28 | 26/28 | 26/28 | 26/28 |
| β | q | r | s | t | u | v |
| 0.25 | 4.03+0 | 1.25+0 | 4.67-2 | 8.61-1 | 2.41-1 | 5.24-2 |
| 0.5 | 4.20+0 | 1.31+0 | 1.08-1 | 9.14-1 | 3.08-1 | 8.42-2 |
| 1.0 | 4.35+0 | 1.38+0 | 2.30-1 | 9.82-1 | 4.33-1 | 1.46-1 |
| 2.0 | 4.57+0 | 1.49+0 | 4.44-1 | 1.09+0 | 6.48-1 | 2.54-1 |
| 4.0 | 4.99+0 | 1.68+0 | 7.75-1 | 1.27+0 | 9.86-1 | 4.21-1 |
| 8.0 | 5.78+0 | 2.02+0 | 1.24+0 | 1.57+0 | 1.46+0 | 6.54-1 |
| 16 | 7.00+0 | 2.50+0 | 1.82+0 | 2.00+0 | 2.08+0 | 9.52-1 |
| 32 | 8.51+0 | 3.09+0 | 2.47+0 | 2.51+0 | 2.78+0 | 1.28+0 |
| $\Delta\varepsilon$ | 0.8441 | 0.8427 | 0.8462 | 0.8458 | 0.8385 | 0.8380 |

Table 6.(continued)

| Z_S/Z_N | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 |
|------------------|--------|--------|--------|--------|--------|--------|
| β | q | r | s | t | u | v |
| 0.25 | 4.03+0 | 1.16+0 | 5.64-2 | 9.75-1 | 3.17-1 | 6.29-2 |
| 0.5 | 4.20+0 | 1.22+0 | 1.18-1 | 1.03+0 | 3.86-1 | 9.50-2 |
| 1.0 | 4.36+0 | 1.29+0 | 2.40-1 | 1.10+0 | 5.12-1 | 1.57-1 |
| 2.0 | 4.59+0 | 1.40+0 | 4.55-1 | 1.21+0 | 7.29-1 | 2.65-1 |
| 4.0 | 5.02+0 | 1.60+0 | 7.87-1 | 1.40+0 | 1.07+0 | 4.34-1 |
| 8.0 | 5.81+0 | 1.92+0 | 1.25+0 | 1.71+0 | 1.56+0 | 6.70-1 |
| 16 | 7.04+0 | 2.40+0 | 1.84+0 | 2.16+0 | 2.19+0 | 9.71-1 |
| 32 | 8.57+0 | 2.98+0 | 2.49+0 | 2.70+0 | 2.91+0 | 1.31+0 |
| $\Delta\epsilon$ | 0.8393 | 0.8376 | 0.8414 | 0.8409 | 0.8337 | 0.8332 |
| Z_S/Z_N | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 |
| β | q | r | s | t | u | v |
| 0.25 | 3.95+0 | 1.08+0 | 7.77-2 | 1.07+0 | 4.03-1 | 7.47-2 |
| 0.5 | 4.12+0 | 1.14+0 | 1.40-1 | 1.13+0 | 4.75-1 | 1.07-1 |
| 1.0 | 4.28+0 | 1.21+0 | 2.63-1 | 1.20+0 | 6.01-1 | 1.70-1 |
| 2.0 | 4.51+0 | 1.32+0 | 4.78-1 | 1.31+0 | 8.20-1 | 2.78-1 |
| 4.0 | 4.95+0 | 1.52+0 | 8.12-1 | 1.50+0 | 1.17+0 | 4.48-1 |
| 8.0 | 5.76+0 | 1.84+0 | 1.28+0 | 1.83+0 | 1.67+0 | 6.87-1 |
| 16 | 6.99+0 | 2.31+0 | 1.87+0 | 2.29+0 | 2.32+0 | 9.93-1 |
| 32 | 8.51+0 | 2.87+0 | 2.53+0 | 2.85+0 | 3.06+0 | 1.34+0 |
| $\Delta\epsilon$ | 0.8355 | 0.8334 | 0.8374 | 0.8371 | 0.8298 | 0.8293 |
| Z_S/Z_N | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 |
| β | q | r | s | t | u | v |
| 0.25 | 3.91+0 | 1.01+0 | 1.08-1 | 1.15+0 | 4.99-1 | 8.79-2 |
| 0.5 | 4.08+0 | 1.06+0 | 1.72-1 | 1.21+0 | 5.75-1 | 1.21-1 |
| 1.0 | 4.25+0 | 1.14+0 | 2.94-1 | 1.29+0 | 7.04-1 | 1.84-1 |
| 2.0 | 4.48+0 | 1.25+0 | 5.10-1 | 1.40+0 | 9.23-1 | 2.93-1 |
| 4.0 | 4.92+0 | 1.44+0 | 8.45-1 | 1.60+0 | 1.27+0 | 4.64-1 |
| 8.0 | 5.72+0 | 1.77+0 | 1.31+0 | 1.93+0 | 1.78+0 | 7.06-1 |
| 16 | 6.95+0 | 2.23+0 | 1.91+0 | 2.41+0 | 2.46+0 | 1.02+0 |
| 32 | 8.48+0 | 2.78+0 | 2.59+0 | 2.99+0 | 3.23+0 | 1.36+0 |
| $\Delta\epsilon$ | 0.8325 | 0.8301 | 0.8343 | 0.8339 | 0.8267 | 0.8275 |

Table 6.(continued)

| Z_S/Z_N | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 |
|------------------|--------|--------|--------|--------|--------|--------|
| β | q | r | s | t | u | v |
| 0.25 | 3.82+0 | 9.43-1 | 1.45-1 | 1.22+0 | 6.00-1 | 1.02-1 |
| 0.5 | 3.99+0 | 1.00+0 | 2.09-1 | 1.29+0 | 6.78-1 | 1.35-1 |
| 1.0 | 4.15+0 | 1.07+0 | 3.32-1 | 1.36+0 | 8.08-1 | 1.98-1 |
| 2.0 | 4.38+0 | 1.18+0 | 5.47-1 | 1.47+0 | 1.03+0 | 3.08-1 |
| 4.0 | 4.82+0 | 1.38+0 | 8.83-1 | 1.67+0 | 1.38+0 | 4.80-1 |
| 8.0 | 5.62+0 | 1.70+0 | 1.36+0 | 2.01+0 | 1.90+0 | 7.23-1 |
| 16 | 6.85+0 | 2.15+0 | 1.96+0 | 2.51+0 | 2.60+0 | 1.04+0 |
| 32 | 8.36+0 | 2.69+0 | 2.64+0 | 3.10+0 | 3.39+0 | 1.39+0 |
| $\Delta\epsilon$ | 0.8301 | 0.8273 | 0.8320 | 0.8315 | 0.8241 | 0.8235 |

| Z_S/Z_N | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 |
|------------------|--------|--------|--------|--------|--------|--------|
| β | q | r | s | t | u | v |
| 0.25 | 3.48+0 | 8.03-1 | 2.63-1 | 1.35+0 | 8.81-1 | 1.46-1 |
| 0.5 | 3.65+0 | 8.58-1 | 3.30-1 | 1.42+0 | 9.69-1 | 1.81-1 |
| 1.0 | 3.81+0 | 9.29-1 | 4.54-1 | 1.50+0 | 1.10+0 | 2.45-1 |
| 2.0 | 4.05+0 | 1.04+0 | 6.69-1 | 1.62+0 | 1.33+0 | 3.55-1 |
| 4.0 | 4.49+0 | 1.24+0 | 1.01+0 | 1.82+0 | 1.69+0 | 5.30-1 |
| 8.0 | 5.28+0 | 1.55+0 | 1.49+0 | 2.18+0 | 2.25+0 | 7.79-1 |
| 16 | 6.46+0 | 1.98+0 | 2.11+0 | 2.69+0 | 2.99+0 | 1.10+0 |
| 32 | 7.91+0 | 2.49+0 | 2.82+0 | 3.33+0 | 3.86+0 | 1.47+0 |
| $\Delta\epsilon$ | 0.8265 | 0.8222 | 0.8283 | 0.8277 | 0.8195 | 0.8242 |

Table 7. Rate coefficients 1s-2s excitation (R_C) for emission lines $1s^2 2p - 1s 2s^2$, $1s^2 2p - 1s 2p^2$ of Li-like ions: $R = 10^{-8} \frac{R_C}{Z_S^3} \exp(-\beta \Delta \epsilon)$ in cm^3/s

Designations: o= $2s^2 1s^2 S_{1/2} - 1s^2 2p^2 P_{3/2}$, p= $2s^2 1s^2 S_{1/2} - 1s^2 2p^2 P_{1/2}$,
 m= $2p^2 1s^2 S_{1/2} - 1s^2 2p^2 P_{3/2}$, n= $2p^2 1s^2 S_{1/2} - 1s^2 2p^2 P_{1/2}$, c= $2p^2 1s^2 P_{1/2} - 1s^2 2p^2 P_{3/2}$,
 d= $2p^2 1s^2 P_{1/2} - 1s^2 2p^2 P_{1/2}$, h= $2p^2 1s^4 P_{1/2} - 1s^2 2p^2 P_{3/2}$, i= $2p^2 1s^4 P_{1/2} - 1s^2 2p^2 P_{1/2}$,

| Z_S/Z_N | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 | 4/6 |
|-------------------|--------|--------|--------|--------|--------|--------|---------|--------|
| β | o | p | m | n | c | d | h | i |
| 0.25 | 2.16-5 | 1.08-5 | 1.05-4 | 5.14-5 | 3.72-8 | 7.50-8 | 3.00-11 | 2.11-8 |
| 0.5 | 2.91-5 | 1.47-5 | 1.75-4 | 8.54-5 | 6.19-8 | 1.25-7 | 4.69-11 | 3.29-8 |
| 1.0 | 3.96-5 | 1.99-5 | 2.90-4 | 1.42-4 | 1.03-7 | 2.07-7 | 7.45-11 | 5.22-8 |
| 2.0 | 5.40-5 | 2.72-5 | 4.70-4 | 2.30-4 | 1.67-7 | 3.36-7 | 1.18-10 | 8.28-8 |
| 4.0 | 7.39-5 | 3.72-5 | 7.46-4 | 3.65-4 | 2.64-7 | 5.33-7 | 1.85-10 | 1.29-7 |
| 8.0 | 1.01-4 | 5.08-5 | 1.16-3 | 5.65-4 | 4.09-7 | 8.24-7 | 2.81-10 | 1.97-7 |
| 16 | 1.36-4 | 6.84-5 | 1.70-3 | 8.33-4 | 6.04-7 | 1.22-6 | 4.09-10 | 2.87-7 |
| 32 | 1.76-4 | 8.84-5 | 2.34-3 | 1.15-3 | 8.31-7 | 1.67-6 | 5.58-10 | 3.91-7 |
| $\Delta \epsilon$ | 1.3392 | 1.3392 | 1.4377 | 1.4377 | 1.4130 | 1.4130 | 1.3951 | 1.3951 |

| Z_S/Z_N | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 | 5/7 |
|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| β | o | p | m | n | c | d | h | i |
| 0.25 | 5.29-5 | 2.67-5 | 2.67-4 | 1.29-4 | 1.18-7 | 2.38-7 | 1.17-9 | 1.49-7 |
| 0.5 | 7.18-5 | 3.63-5 | 4.21-4 | 2.04-4 | 1.86-7 | 3.76-7 | 1.75-9 | 2.22-7 |
| 1.0 | 9.76-5 | 4.93-5 | 6.73-4 | 3.26-4 | 2.98-7 | 6.02-7 | 2.66-9 | 3.39-7 |
| 2.0 | 1.33-4 | 6.70-5 | 1.08-3 | 5.21-4 | 4.76-7 | 9.61-7 | 4.09-9 | 5.21-7 |
| 4.0 | 1.80-4 | 9.08-5 | 1.68-3 | 8.16-4 | 7.46-7 | 1.50-6 | 6.22-9 | 7.91-7 |
| 28.0 | 2.43-4 | 1.23-4 | 2.54-3 | 1.23-3 | 1.13-6 | 2.27-6 | 9.18-9 | 1.17-6 |
| 16 | 3.25-4 | 1.64-4 | 3.66-3 | 1.78-3 | 1.62-6 | 3.27-6 | 1.31-8 | 1.66-6 |
| 32 | 4.18-4 | 2.11-4 | 4.99-3 | 2.42-3 | 2.21-6 | 4.45-6 | 1.76-8 | 2.24-6 |
| $\Delta \epsilon$ | 1.2079 | 1.2079 | 1.2847 | 1.2847 | 1.2661 | 1.2661 | 1.2505 | 1.2505 |

| Z_S/Z_N | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 | 6/8 |
|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| β | o | p | m | n | c | d | h | i |
| 0.25 | 1.11-4 | 5.64-5 | 5.72-4 | 2.69-4 | 4.65-7 | 9.44-7 | 1.29-8 | 8.85-7 |
| 0.5 | 1.51-4 | 7.68-5 | 8.77-4 | 4.13-4 | 7.13-7 | 1.45-6 | 1.76-8 | 1.21-6 |
| 1.0 | 2.06-4 | 1.04-4 | 1.36-3 | 6.40-4 | 1.11-6 | 2.25-6 | 2.39-8 | 1.64-6 |
| 2.0 | 2.79-4 | 1.42-4 | 2.10-3 | 9.90-4 | 1.71-6 | 3.48-6 | 3.25-8 | 2.22-6 |
| 4.0 | 3.78-4 | 1.92-4 | 3.23-3 | 1.52-3 | 2.62-6 | 5.33-6 | 4.40-8 | 3.02-6 |
| 8.0 | 5.12-4 | 2.60-4 | 4.82-3 | 2.27-3 | 3.92-6 | 7.96-6 | 5.96-8 | 4.08-6 |
| 16 | 6.84-4 | 3.47-4 | 6.92-3 | 3.26-3 | 5.63-6 | 1.14-5 | 7.96-8 | 5.45-6 |
| 32 | 8.81-4 | 4.47-4 | 9.40-3 | 4.42-3 | 7.65-6 | 1.55-5 | 1.02-7 | 7.02-6 |
| $\Delta \epsilon$ | 1.1242 | 1.1242 | 1.1872 | 1.1872 | 1.1722 | 1.1722 | 1.1586 | 1.1586 |

Table 7. (continued)

| Z_S/Z_N 8/10 | | 8/10 | 8/10 | 8/10 | 8/10 | 8/10 | 8/10 | 8/10 |
|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| β | o | p | m | n | c | d | h | i |
| 0.25 | 3.55-4 | 1.83-4 | 1.77-3 | 7.81-4 | 2.64-6 | 5.47-6 | 1.47-7 | 5.88-6 |
| 0.5 | 4.85-4 | 2.50-4 | 2.64-3 | 1.16-3 | 3.93-6 | 8.13-6 | 2.10-7 | 8.44-6 |
| 1.0 | 6.64-4 | 3.42-4 | 3.95-3 | 1.74-3 | 5.88-6 | 1.22-5 | 3.06-7 | 1.23-5 |
| 2.0 | 9.08-4 | 4.68-4 | 5.94-3 | 2.61-3 | 8.84-6 | 1.83-5 | 4.46-7 | 1.79-5 |
| 4.0 | 1.24-3 | 6.38-4 | 8.90-3 | 3.92-3 | 1.32-5 | 2.74-5 | 6.50-7 | 2.61-5 |
| 8.0 | 1.68-3 | 8.65-4 | 1.30-2 | 5.73-3 | 1.94-5 | 4.02-5 | 9.30-7 | 3.73-5 |
| 16 | 2.24-3 | 1.16-3 | 1.84-2 | 8.08-3 | 2.73-5 | 5.66-5 | 1.29-6 | 5.18-5 |
| 32 | 2.88-3 | 1.48-3 | 2.47-2 | 1.09-2 | 3.67-5 | 7.61-5 | 1.71-6 | 6.87-5 |
| $\Delta\varepsilon$ | 1.0240 | 1.0240 | 1.0704 | 1.0704 | 1.0597 | 1.0597 | 1.0488 | 1.0488 |
| | | | | | | | | |
| Z_S/Z_N 10/12 | | 10/12 | 10/12 | 10/12 | 10/12 | 10/12 | 10/12 | 10/12 |
| β | o | p | m | n | c | d | h | i |
| 0.25 | 8.65-4 | 4.62-4 | 3.86-3 | 1.42-3 | 9.60-6 | 2.05-5 | 8.00-7 | 2.60-5 |
| 0.5 | 1.19-3 | 6.34-4 | 5.65-3 | 2.08-3 | 1.40-5 | 3.00-5 | 1.14-6 | 3.70-5 |
| 1.0 | 1.63-3 | 8.69-4 | 8.38-3 | 3.09-3 | 2.08-5 | 4.45-5 | 1.64-6 | 5.34-5 |
| 2.0 | 2.23-3 | 1.19-3 | 1.25-2 | 4.60-3 | 3.10-5 | 6.63-5 | 2.38-6 | 7.75-5 |
| 4.0 | 3.04-3 | 1.63-3 | 1.84-2 | 6.76-3 | 4.56-5 | 9.75-5 | 3.43-6 | 1.12-4 |
| 8.0 | 4.14-3 | 2.21-3 | 2.66-2 | 9.81-3 | 6.62-5 | 1.41-4 | 4.87-6 | 1.59-4 |
| 16 | 5.54-3 | 2.96-3 | 3.77-2 | 1.39-2 | 9.37-5 | 2.00-4 | 6.78-6 | 2.21-4 |
| 32 | 7.13-3 | 3.81-3 | 5.07-2 | 1.87-2 | 1.26-4 | 2.69-4 | 9.01-6 | 2.93-4 |
| $\Delta\varepsilon$ | 0.9663 | 0.9663 | 1.0032 | 1.0032 | 0.9948 | 0.9948 | 0.9858 | 0.9858 |
| | | | | | | | | |
| Z_S/Z_N 11/13 | | 11/13 | 11/13 | 11/13 | 11/13 | 11/13 | 11/13 | 11/13 |
| β | o | p | m | n | c | d | h | i |
| 0.25 | 1.26-3 | 6.88-4 | 5.26-3 | 1.95-3 | 1.66-5 | 3.61-5 | 1.53-6 | 4.81-5 |
| 0.5 | 1.73-3 | 9.45-4 | 7.64-3 | 2.83-3 | 2.41-5 | 5.24-5 | 2.17-6 | 6.81-5 |
| 1.0 | 2.37-3 | 1.30-3 | 1.12-2 | 4.17-3 | 3.54-5 | 7.70-5 | 3.10-6 | 9.74-5 |
| 2.0 | 3.25-3 | 1.78-3 | 1.66-2 | 6.17-3 | 5.24-5 | 1.14-4 | 4.46-6 | 1.40-4 |
| 4.0 | 4.44-3 | 2.43-3 | 2.44-2 | 9.06-3 | 7.70-5 | 1.68-4 | 6.41-6 | 2.02-4 |
| 8.0 | 6.04-3 | 3.30-3 | 3.52-2 | 1.30-2 | 1.11-4 | 2.41-4 | 9.09-6 | 2.86-4 |
| 16 | 8.08-3 | 4.42-3 | 4.91-2 | 1.82-2 | 1.55-4 | 3.36-4 | 1.25-5 | 3.94-4 |
| 32 | 1.04-2 | 5.70-3 | 6.53-2 | 2.42-2 | 2.06-4 | 4.48-4 | 1.65-5 | 5.20-4 |
| $\Delta\varepsilon$ | 0.9459 | 0.9459 | 0.9794 | 0.9794 | 0.9718 | 0.0718 | 0.9635 | 0.9635 |

Table 7. (continued)

| Z_S/Z_N 12/14 | | | | | | | | |
|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| β | o | p | m | n | c | d | h | i |
| 0.25 | 3.13-3 | 1.84-3 | 1.02-2 | 2.85-3 | 6.04-5 | 1.42-4 | 6.17-6 | 2.07-4 |
| 0.5 | 4.30-3 | 2.53-3 | 1.46-2 | 4.07-3 | 8.65-5 | 2.04-4 | 8.69-6 | 2.92-4 |
| 1.0 | 5.91-3 | 3.48-3 | 2.10-2 | 5.86-3 | 1.24-4 | 2.93-4 | 1.23-5 | 4.13-4 |
| 2.0 | 8.13-3 | 4.78-3 | 3.03-2 | 8.44-3 | 1.79-4 | 4.22-4 | 1.75-5 | 5.87-4 |
| 4.0 | 1.12-2 | 6.56-3 | 4.36-2 | 1.22-2 | 2.58-4 | 6.09-4 | 2.49-5 | 8.34-4 |
| 8.0 | 1.52-2 | 8.95-3 | 6.26-2 | 1.75-2 | 3.71-4 | 8.74-4 | 3.52-5 | 1.18-3 |
| 16 | 2.04-2 | 1.20-2 | 8.79-2 | 2.45-2 | 5.20-4 | 1.23-3 | 4.88-5 | 1.64-3 |
| 32 | 2.63-2 | 1.55-2 | 1.17-1 | 3.26-2 | 6.93-4 | 1.63-3 | 6.44-5 | 2.16-3 |
| $\Delta\varepsilon$ | 0.9290 | 0.9290 | 0.9598 | 0.9598 | 0.9526 | 0.9526 | 0.9452 | 0.9452 |
| Z_S/Z_N 14/16 | | | | | | | | |
| β | o | p | m | n | c | d | h | i |
| 0.25 | 3.13-3 | 1.84-3 | 1.02-2 | 2.85-3 | 6.04-5 | 1.42-4 | 6.17-6 | 2.07-4 |
| 0.5 | 4.30-3 | 2.53-3 | 1.46-2 | 4.07-3 | 8.65-5 | 2.04-4 | 8.69-6 | 2.92-4 |
| 1.0 | 5.91-3 | 3.48-3 | 2.10-2 | 5.86-3 | 1.24-4 | 2.93-4 | 1.23-5 | 4.13-4 |
| 2.0 | 8.13-3 | 4.78-3 | 3.03-2 | 8.44-3 | 1.79-4 | 4.22-4 | 1.75-5 | 5.87-4 |
| 4.0 | 1.12-2 | 6.56-3 | 4.36-2 | 1.22-2 | 2.58-4 | 6.09-4 | 2.49-5 | 8.34-4 |
| 8.0 | 1.52-2 | 8.95-3 | 6.26-2 | 1.75-2 | 3.71-4 | 8.74-4 | 3.52-5 | 1.18-3 |
| 16 | 2.04-2 | 1.20-2 | 8.79-2 | 2.45-2 | 5.20-4 | 1.23-3 | 4.88-5 | 1.64-3 |
| 32 | 2.63-2 | 1.55-2 | 1.17-1 | 3.26-2 | 6.93-4 | 1.63-3 | 6.44-5 | 2.16-3 |
| $\Delta\varepsilon$ | 0.9031 | 0.9031 | 0.9297 | 0.9297 | 0.9236 | 0.9236 | 0.9170 | 0.9170 |
| Z_S/Z_N 18/20 | | | | | | | | |
| β | o | p | m | n | c | d | h | i |
| 0.25 | 7.61-3 | 5.24-3 | 1.56-2 | 2.46-3 | 1.83-4 | 4.93-4 | 1.67-5 | 8.54-4 |
| 0.5 | 1.05-2 | 7.21-3 | 2.22-2 | 3.49-3 | 2.60-4 | 7.01-4 | 2.34-5 | 1.20-3 |
| 1.0 | 1.44-2 | 9.93-3 | 3.17-2 | 4.99-3 | 3.72-4 | 1.00-3 | 3.31-5 | 1.70-3 |
| 2.0 | 1.99-2 | 1.37-2 | 4.55-2 | 7.17-3 | 5.34-4 | 1.44-3 | 4.70-5 | 2.41-3 |
| 4.0 | 2.73-2 | 1.88-2 | 6.51-2 | 1.02-2 | 7.63-4 | 2.06-3 | 6.65-5 | 3.41-3 |
| 8.0 | 3.73-2 | 2.57-2 | 9.20-2 | 1.45-2 | 1.08-3 | 2.90-3 | 9.32-5 | 4.78-3 |
| 16 | 5.01-2 | 3.45-2 | 1.27-1 | 2.00-2 | 1.49-3 | 4.00-3 | 1.28-4 | 6.56-3 |
| 32 | 6.47-2 | 4.45-2 | 1.67-1 | 2.63-2 | 1.96-3 | 5.28-3 | 1.68-4 | 8.61-3 |
| $\Delta\varepsilon$ | 0.8696 | 0.8696 | 0.8911 | 0.8911 | 0.8860 | 0.8860 | 0.8807 | 0.8807 |

Table 7. (continued)

| Z_S/Z_N 20/22 | | | | | | | | |
|------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| β | o | p | m | n | c | d | h | i |
| 0.25 | 1.08-2 | 8.11-3 | 1.70-2 | 1.85-3 | 2.58-4 | 7.52-4 | 2.02-5 | 1.49-3 |
| 0.5 | 1.48-2 | 1.12-2 | 2.40-2 | 2.61-3 | 3.64-4 | 1.06-3 | 2.83-5 | 2.09-3 |
| 1.0 | 2.04-2 | 1.54-2 | 3.41-2 | 3.70-3 | 5.17-4 | 1.51-3 | 3.98-5 | 2.94-3 |
| 2.0 | 2.80-2 | 2.11-2 | 4.87-2 | 5.29-3 | 7.39-4 | 2.15-3 | 5.64-5 | 4.17-3 |
| 4.0 | 3.85-2 | 2.90-2 | 6.97-2 | 7.56-3 | 1.06-3 | 3.08-3 | 7.99-5 | 5.91-3 |
| 8.0 | 5.26-2 | 3.96-2 | 9.84-2 | 1.07-2 | 1.49-3 | 4.35-3 | 1.12-4 | 8.29-3 |
| 16 | 7.07-2 | 5.33-2 | 1.36-1 | 1.47-2 | 2.06-3 | 5.99-3 | 1.54-4 | 1.14-2 |
| 32 | 9.12-2 | 6.88-2 | 1.78-1 | 1.94-2 | 2.70-3 | 7.88-3 | 2.02-4 | 1.49-2 |
| $\Delta\epsilon$ | 0.8584 | 0.8584 | 0.8783 | 0.8783 | 0.8735 | 0.8735 | 0.8686 | 0.8686 |
| Z_S/Z_N 24/26 | | | | | | | | |
| β | o | p | m | n | c | d | h | i |
| 0.25 | 2.15-2 | 2.39-2 | 1.57-2 | 4.31-4 | 3.68-4 | 1.27-3 | 9.52-6 | 4.98-3 |
| 0.5 | 2.97-2 | 3.30-2 | 2.19-2 | 6.03-4 | 5.15-4 | 1.78-3 | 1.33-5 | 6.94-3 |
| 1.0 | 4.08-2 | 4.54-2 | 3.09-2 | 8.50-4 | 7.25-4 | 2.50-3 | 1.87-5 | 9.75-3 |
| 2.0 | 5.61-2 | 6.24-2 | 4.39-2 | 1.21-3 | 1.03-3 | 3.55-3 | 2.64-5 | 1.38-2 |
| 4.0 | 7.72-2 | 8.58-2 | 6.23-2 | 1.71-3 | 1.46-3 | 5.05-3 | 3.75-5 | 1.96-2 |
| 8.0 | 1.06-1 | 1.17-1 | 8.78-2 | 2.41-3 | 2.06-3 | 7.11-3 | 5.27-5 | 2.76-2 |
| 16 | 1.42-1 | 1.58-1 | 1.21-1 | 3.32-3 | 2.84-3 | 9.80-3 | 7.25-5 | 3.79-2 |
| 32 | 1.83-1 | 2.04-1 | 1.59-1 | 4.37-3 | 3.73-3 | 1.29-2 | 9.52-5 | 4.98-2 |
| $\Delta\epsilon$ | 0.8423 | 0.8423 | 0.8604 | 0.8604 | 0.8556 | 0.8556 | 0.8513 | 0.8513 |
| Z_S/Z_N 26/28 | | | | | | | | |
| β | o | p | m | n | c | d | h | i |
| 0.25 | 2.15-2 | 2.39-2 | 1.57-2 | 4.31-4 | 3.68-4 | 1.27-3 | 9.52-6 | 4.98-3 |
| 0.5 | 2.97-2 | 3.30-2 | 2.19-2 | 6.03-4 | 5.15-4 | 1.78-3 | 1.33-5 | 6.94-3 |
| 1.0 | 4.08-2 | 4.54-2 | 3.09-2 | 8.50-4 | 7.25-4 | 2.50-3 | 1.87-5 | 9.75-3 |
| 2.0 | 5.61-2 | 6.24-2 | 4.39-2 | 1.21-3 | 1.03-3 | 3.55-3 | 2.64-5 | 1.38-2 |
| 4.0 | 7.72-2 | 8.58-2 | 6.23-2 | 1.71-3 | 1.46-3 | 5.05-3 | 3.75-5 | 1.96-2 |
| 8.0 | 1.06-1 | 1.17-1 | 8.78-2 | 2.41-3 | 2.06-3 | 7.11-3 | 5.27-5 | 2.76-2 |
| 16 | 1.42-1 | 1.58-1 | 1.21-1 | 3.32-3 | 2.84-3 | 9.80-3 | 7.25-5 | 3.79-2 |
| 32 | 1.83-1 | 2.04-1 | 1.59-1 | 4.37-3 | 3.73-3 | 1.29-2 | 9.52-5 | 4.98-2 |
| $\Delta\epsilon$ | 0.8365 | 0.8365 | 0.8541 | 0.8541 | 0.8492 | 0.8492 | 0.8450 | 0.8450 |

Table 7. (continued)

| | | | | | | | | |
|------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Z_S/Z_N | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 | 28/30 |
| β | o | p | m | n | c | d | h | i |
| 0.25 | 2.49-2 | 3.22-2 | 1.42-2 | 2.34-4 | 3.49-4 | 1.22-3 | 3.87-6 | 6.58-3 |
| 0.5 | 3.42-2 | 4.44-2 | 1.99-2 | 3.26-4 | 4.87-4 | 1.71-3 | 5.40-6 | 9.19-3 |
| 1.0 | 4.71-2 | 6.11-2 | 2.79-2 | 4.58-4 | 6.84-4 | 2.40-3 | 7.58-6 | 1.29-2 |
| 2.0 | 6.48-2 | 8.40-2 | 3.94-2 | 6.48-4 | 9.67-4 | 3.39-3 | 1.07-5 | 1.82-2 |
| 4.0 | 8.91-2 | 1.15-1 | 5.58-2 | 9.17-4 | 1.37-3 | 4.80-3 | 1.51-5 | 2.58-2 |
| 8.0 | 1.22-1 | 1.58-1 | 7.86-2 | 1.29-3 | 1.93-3 | 6.75-3 | 2.13-5 | 3.62-2 |
| 16 | 1.64-1 | 2.12-1 | 1.08-1 | 1.78-3 | 2.65-3 | 9.30-3 | 2.93-5 | 4.99-2 |
| 32 | 2.11-1 | 2.74-1 | 1.42-1 | 2.34-3 | 3.49-3 | 1.22-2 | 3.85-5 | 6.56-2 |
| $\Delta\epsilon$ | 0.8317 | 0.8317 | 0.8491 | 0.8491 | 0.8440 | 0.8440 | 0.8399 | 0.8399 |
| Z_S/Z_N | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 | 30/32 |
| β | o | p | m | n | c | d | h | i |
| 0.25 | 2.79-2 | 4.27-2 | 9.98-3 | 9.67-5 | 3.07-4 | 1.07-3 | 6.15-7 | 8.25-3 |
| 0.5 | 3.83-2 | 5.87-2 | 1.39-2 | 1.35-4 | 4.29-4 | 1.49-3 | 8.58-7 | 1.15-2 |
| 1.0 | 5.27-2 | 8.08-2 | 1.95-2 | 1.89-4 | 6.01-4 | 2.09-3 | 1.20-6 | 1.61-2 |
| 2.0 | 7.25-2 | 1.11-1 | 2.75-2 | 2.66-4 | 8.46-4 | 2.95-3 | 1.69-6 | 2.27-2 |
| 4.0 | 9.96-2 | 1.53-1 | 3.88-2 | 3.76-4 | 1.19-3 | 4.16-3 | 2.39-6 | 3.21-2 |
| 8.0 | 1.36-1 | 2.09-1 | 5.45-2 | 5.28-4 | 1.68-3 | 5.84-3 | 3.36-6 | 4.51-2 |
| 16 | 1.83-1 | 2.81-1 | 7.50-2 | 7.26-4 | 2.31-3 | 8.04-3 | 4.62-6 | 6.20-2 |
| 32 | 2.37-1 | 3.62-1 | 9.85-2 | 9.54-4 | 3.03-3 | 1.06-2 | 6.07-6 | 8.15-2 |
| $\Delta\epsilon$ | 0.8278 | 0.8278 | 0.8452 | 0.8452 | 0.8399 | 0.8399 | 0.8357 | 0.8357 |
| Z_S/Z_N | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 | 32/34 |
| β | o | p | m | n | c | d | h | i |
| 0.25 | 3.02-2 | 5.47-2 | 1.09-2 | 6.24-5 | 2.53-4 | 8.65-4 | 9.85-8 | 9.88-3 |
| 0.5 | 4.15-2 | 7.52-2 | 1.52-2 | 8.69-5 | 3.53-4 | 1.21-3 | 1.37-7 | 1.38-2 |
| 1.0 | 5.70-2 | 1.03-1 | 2.13-2 | 1.22-4 | 4.94-4 | 1.69-3 | 1.92-7 | 1.93-2 |
| 2.0 | 7.83-2 | 1.42-1 | 3.00-2 | 1.71-4 | 6.95-4 | 2.37-3 | 2.70-7 | 2.71-2 |
| 4.0 | 1.08-1 | 1.95-1 | 4.22-2 | 2.41-4 | 9.79-4 | 3.34-3 | 3.80-7 | 3.82-2 |
| 8.0 | 1.47-1 | 2.67-1 | 5.92-2 | 3.38-4 | 1.37-3 | 4.68-3 | 5.33-7 | 5.35-2 |
| 16 | 1.98-1 | 3.59-1 | 8.13-2 | 4.64-4 | 1.88-3 | 6.43-3 | 7.32-7 | 7.35-2 |
| 32 | 2.56-1 | 4.64-1 | 1.07-1 | 6.09-4 | 2.47-3 | 8.45-3 | 9.61-7 | 9.64-2 |
| $\Delta\epsilon$ | 0.8247 | 0.8247 | 0.8244 | 0.8244 | 0.8366 | 0.8366 | 0.8322 | 0.8322 |

Table 7. (continued)

| Z_S/Z_N | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 | 34/36 |
|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| β | o | p | m | n | c | d | h | i |
| 0.25 | 3.18-2 | 6.86-2 | 8.43-3 | 2.86-5 | 1.99-4 | 6.56-4 | 1.51-6 | 1.13-2 |
| 0.5 | 4.37-2 | 9.42-2 | 1.18-2 | 3.98-5 | 2.77-4 | 9.14-4 | 2.10-6 | 1.58-2 |
| 1.0 | 5.99-2 | 1.29-1 | 1.64-2 | 5.57-5 | 3.88-4 | 1.28-3 | 2.94-6 | 2.21-2 |
| 2.0 | 8.22-2 | 1.77-1 | 2.31-2 | 7.83-5 | 5.44-4 | 1.79-3 | 4.12-6 | 3.10-2 |
| 4.0 | 1.13-1 | 2.44-1 | 3.25-2 | 1.10-4 | 7.65-4 | 2.52-3 | 5.80-6 | 4.37-2 |
| 8.0 | 1.55-1 | 3.34-1 | 4.54-2 | 1.54-4 | 1.07-3 | 3.53-3 | 8.11-6 | 6.11-2 |
| 16 | 2.08-1 | 4.49-1 | 6.23-2 | 2.11-4 | 1.47-3 | 4.84-3 | 1.11-5 | 8.38-2 |
| 32 | 2.69-1 | 5.80-1 | 8.17-2 | 2.77-4 | 1.93-3 | 6.35-3 | 1.46-5 | 1.10-1 |
| $\Delta\varepsilon$ | 0.8221 | 0.8221 | 0.8401 | 0.8401 | 0.8341 | 0.8341 | 0.8295 | 0.8295 |

| Z_S/Z_N | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 | 40/42 |
|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| β | o | p | m | n | c | d | h | i |
| 0.25 | 3.22-2 | 1.19-1 | 5.66-3 | 4.60-6 | 7.71-5 | 2.27-4 | 8.08-6 | 1.55-2 |
| 0.5 | 4.41-2 | 1.63-1 | 7.85-3 | 6.38-6 | 1.07-4 | 3.15-4 | 1.11-5 | 2.12-2 |
| 1.0 | 6.04-2 | 2.24-1 | 1.09-2 | 8.88-6 | 1.49-4 | 4.39-4 | 1.52-5 | 2.90-2 |
| 2.0 | 8.28-2 | 3.07-1 | 1.53-2 | 1.24-5 | 2.08-4 | 6.14-4 | 2.08-5 | 3.98-2 |
| 4.0 | 1.14-1 | 4.21-1 | 2.14-2 | 1.74-5 | 2.92-4 | 8.60-4 | 2.86-5 | 5.47-2 |
| 8.0 | 1.56-1 | 5.76-1 | 2.99-2 | 2.43-5 | 4.07-4 | 1.20-3 | 3.91-5 | 7.48-2 |
| 16 | 2.09-1 | 7.75-1 | 4.09-2 | 3.33-5 | 5.57-4 | 1.64-3 | 5.26-5 | 1.01-1 |
| 32 | 2.70-1 | 1.00+0 | 5.36-2 | 4.36-5 | 7.30-4 | 2.15-3 | 6.79-5 | 1.30-1 |
| $\Delta\varepsilon$ | 0.8175 | 0.8175 | 0.8372 | 0.8372 | 0.8300 | 0.8300 | 0.8189 | 0.8189 |

Table 8. Excitation cross section in units 10^{-22} cm^2 for TiXX and FeXXIV.

a: present calculations, b - theoretical data by Zhang et al [31], c- experiment results by Wong et al [17]. Designations are the same as in Table 4.

| Ion | Energy(keV) | q | r | s | t | u | v | |
|-------------------|-------------|---|-----------|-----------|-------|-----------|-----------|-----------|
| Ti ¹⁹⁺ | 4.9 | a | 4.65 | 1.94 | 1.47 | 1.12 | 1.43 | 0.692 |
| Ti ¹⁹⁺ | 4.9 | b | 4.88 | 2.03 | | 1.21 | 1.47 | 0.73 |
| Ti ¹⁹⁺ | 4.9 | c | 4.64±1.06 | 2.18±0.54 | | 1.00±0.27 | 2.29±0.58 | 0.97±0.25 |
| Fe ²³⁺ | 6.8 | a | 2.38 | 0.813 | 0.742 | 0.665 | 0.787 | 0.374 |
| Fe ²³⁺ | 6.8 | b | 2.49 | 0.94 | | 0.72 | 0.81 | 0.39 |
| Fe ²³⁺ | 6.8 | c | 2.41±0.33 | 1.06±0.18 | | 0.74±0.13 | 0.77±0.13 | 0.39±0.07 |

Table 9. Excitation rate coefficients (cm^3/s) -R for FeXXIV:

a- present calculations, b- data by Bely-Dubau et al [4].

Designations are from Table 4 and 5.

| T (10^6 K) | a | b | a | b | a | b |
|---------------|---------|---------|---------|---------|---------|---------|
| | q | | r | | s | |
| 5.0 | 1.07-18 | 1.16-18 | 4.03-19 | 3.70-19 | 2.82-19 | 1.17-20 |
| 7.5 | 1.62-16 | | 6.02-17 | | 3.94-17 | |
| 10 | 1.94-15 | 2.06-15 | 7.41-16 | 6.42-16 | 4.35-16 | 1.75-17 |
| 15 | 2.28-14 | 2.41-14 | 8.28-15 | 7.37-15 | 4.42-15 | 1.76-16 |
| 20 | 7.77-14 | 8.16-14 | 2.79-14 | 2.46-14 | 1.44-14 | 5.26-16 |
| 30 | 2.63-13 | 2.74-13 | 9.28-14 | 8.10-14 | 3.52-14 | 1.45-15 |
| 40 | 4.88-13 | 5.00-13 | 1.68-13 | 1.46-13 | 5.29-14 | 2.15-15 |
| 60 | 8.42-13 | 9.10-13 | 2.89-13 | 2.62-13 | 6.71-14 | 2.95-15 |
| 80 | 1.20-12 | 1.22-12 | 4.09-13 | 3.50-13 | 7.41-14 | 3.21-15 |
| 100 | 1.44-12 | 1.46-12 | 4.88-13 | 4.09-13 | 7.47-14 | 3.23-15 |
| 120 | 1.62-12 | | 5.47-13 | | 6.81-14 | |
| 160 | 1.88-12 | | 6.30-13 | | 5.75-14 | |

| T (10^6 K) | t | u | v |
|---------------|---------|---------|-----------------|
| | 5.0 | 2.88-19 | 2.39-19 |
| 7.5 | 4.22-17 | | 4.44-17 |
| 10 | 4.93-16 | 4.05-16 | 4.94-16 4.79-16 |
| 15 | 5.56-15 | 4.57-15 | 5.08-15 4.89-15 |
| 20 | 1.83-14 | 1.51-14 | 1.54-14 1.47-14 |
| 30 | 5.90-14 | 4.85-14 | 4.29-14 4.05-14 |
| 40 | 1.04-13 | 8.61-14 | 6.73-14 6.30-14 |
| 60 | 1.74-13 | 1.52-13 | 9.21-14 9.02-14 |
| 80 | 2.41-13 | 2.00-13 | 1.11-13 1.02-13 |
| 100 | 2.85-13 | 2.35-13 | 1.19-13 1.07-13 |
| 120 | 3.16-13 | | 1.18-13 |
| 160 | 3.59-13 | | 1.16-13 |

Table 9 (continued)

| T (10 ⁶ K) | a | b | a | b | a | b | a | b |
|-----------------------|----------|---------|----------|---------|----------|---------|----------|---------|
| | o | | p | | c | | d | |
| 5.0 | 2.17-20 | 1.82-20 | 2.09-20 | 1.84-20 | 4.10-22 | 4.33-22 | 1.35-21 | 1.48-21 |
| 7.5 | 2.94-18 | | 2.83-18 | | 5.96-18 | | 2.08-19 | |
| 10 | 3.29-17 | 2.95-17 | 3.17-17 | 3.00-17 | 6.87-19 | 7.04-19 | 2.27-18 | 2.41-18 |
| 15 | 3.30-16 | 3.22-16 | 3.18-16 | 3.25-16 | 7.45-18 | 7.63-18 | 2.46-17 | 2.61-17 |
| 20 | 1.05-15 | 1.01-15 | 1.05-15 | 1.02-15 | 2.34-17 | 2.41-17 | 7.74-17 | 8.27-17 |
| 30 | 3.10-15 | 3.05-15 | 3.10-15 | 3.08-15 | 6.92-17 | 7.22-17 | 2.29-16 | 2.47-16 |
| 40 | 5.31-15 | 5.08-15 | 5.12-15 | 5.13-15 | 1.14-16 | 1.20-16 | 3.77-16 | 4.13-16 |
| 60 | 8.31-15 | 8.04-15 | 7.99-15 | 8.12-15 | 1.76-16 | 1.91-16 | 5.83-16 | 6.53-16 |
| 80 | 1.00-14 | 9.75-15 | 9.63-15 | 9.85-15 | 2.10-16 | 2.30-16 | 6.95-16 | 7.88-16 |
| 100 | 1.11-14 | 1.07-14 | 1.06-14 | 1.08-14 | 2.31-16 | 2.55-16 | 7.65-16 | 8.74-16 |
| 120 | 1.14-14 | | 1.10-14 | | 2.36-16 | | 7.83-16 | |
| 160 | 1.17-14 | | 1.13-14 | | 2.41-16 | | 7.98-16 | |
| | h | | i | | m | | n | |
| 5.0 | 1.88-23 | 4.46-23 | 4.25-21 | 4.23-21 | 1.75-20 | 1.79-20 | 7.86-22 | 3.42-22 |
| 7.5 | 2.68-21 | | 6.04-19 | | 2.62-18 | | 1.18-19 | |
| 10 | 3.05-20 | 7.26-20 | 6.87-18 | 6.80-18 | 3.06-17 | 2.90-17 | 1.38-18 | 5.54-19 |
| 15 | 3.26-19 | 7.87-19 | 7.35-17 | 7.46-17 | 3.37-16 | 3.15-16 | 1.51-17 | 6.03-18 |
| 20 | 1.02-18 | 2.48-18 | 2.30-16 | 2.35-16 | 1.07-15 | 9.91-16 | 4.80-17 | 7.89-17 |
| 30 | 3.01-18 | 7.46-18 | 6.78-16 | 7.07-16 | 3.18-15 | 2.98-15 | 1.43-16 | 5.69-17 |
| 40 | 4.94-18 | 1.25-17 | 1.11-15 | 1.18-15 | 5.25-15 | 4.97-15 | 2.36-16 | 9.49-17 |
| 60 | 7.64-18 | 1.97-17 | 1.72-15 | 1.87-15 | 8.16-15 | 7.87-15 | 3.67-16 | 1.50-16 |
| 80 | 9.11-18 | 2.38-17 | 2.05-15 | 2.26-15 | 9.74-15 | 9.56-15 | 4.38-16 | 1.83-16 |
| 100 | 1.00-17 | 2.63-17 | 2.26-15 | 2.49-15 | 1.07-14 | 1.05-14 | 4.82-16 | 2.01-16 |
| 120 | 1.03-17 | | 2.32-15 | | 1.10-14 | | 4.94-16 | |
| 160 | 1.05-17 | | 2.36-15 | | 1.12-14 | | 5.04-16 | |

Figure Captions

Fig. 1. Scaled cross section (σc) for the six $2s2p(^{1,3}P)1s^2\ ^{2,4}P_J - 1s^22s^2\ ^2S_{1/2}$ lines of Li-like ions with $Z = 6, 8, 10, 12, 13, 16, 20, 22, 26, 28, 30, 36$ and 42 as function of the scaled scattered electron energy u , given in units of Zs^2 (Ry), where $Zs = Z-2$.

$$(i) \ q = 2s2p(^3P)1s^2\ ^2P_{2/3} - 1s^22s^2\ ^2S_{1/2}$$

$$(ii) \ r = 2s2p(^3P)1s^2\ ^2P_{1/2} - 1s^22s^2\ ^2S_{1/2}$$

$$(iii) \ s = 2s2p(^1P)1s^2\ ^2P_{3/2} - 1s^22s^2\ ^2S_{1/2}$$

$$(iv) \ t = 2s2p(^1P)1s^2\ ^2P_{1/2} - 1s^22s^2\ ^2S_{1/2}$$

$$(v) \ u = 2s2p(^3P)1s^2\ ^4P_{3/2} - 1s^22s^2\ ^2S_{1/2}$$

$$(vi) \ v = 2s2p(^3P)1s^2\ ^4P_{1/2} - 1s^22s^2\ ^2S_{1/2}$$

Fig. 2. Scaled cross section (σc) for the eight emission lines $1s^22p - 1s2s^2$, $1s^22p - 1s2p^2$ of Li-like ions with $Z = 6, 8, 10, 12, 13, 16, 20, 22, 26, 28, 30, 36$ and 42 as function of the scaled scattered electron energy u , given in units of Zs^2 (Ry), where $Zs = Z-2$.

$$(i) \ o = 2s^21s^2\ ^2S_{1/2} - 1s^22p^2\ ^2P_{3/2}$$

$$(ii) \ p = 2s^21s^2\ ^2S_{1/2} - 1s^22p^2\ ^2P_{1/2}$$

$$(iii) \ m = 2p^21s^2\ ^2S_{1/2} - 1s^22p^2\ ^2P_{3/2}$$

$$(iv) \ n = 2p^21s^2\ ^2S_{1/2} - 1s^22p^2\ ^2P_{1/2}$$

$$(v) \ c = 2p^21s^2\ ^2P_{1/2} - 1s^22p^2\ ^2P_{3/2}$$

$$(vi) \ d = 2p^21s^2\ ^2P_{1/2} - 1s^22p^2\ ^2P_{1/2}$$

$$(vii) \ h = 2p^21s^2\ ^4P_{1/2} - 1s^22p^2\ ^2P_{3/2}$$

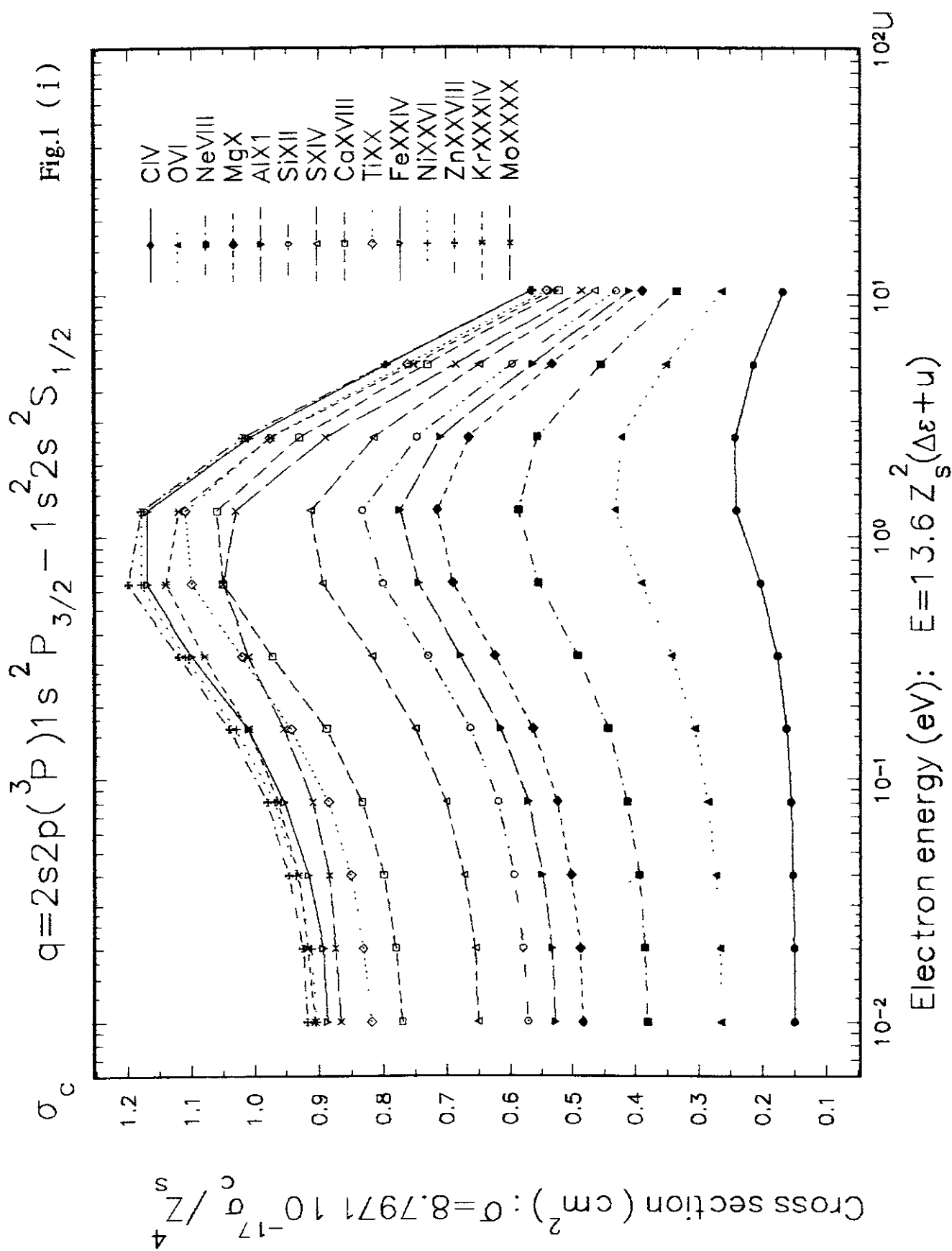
$$(viii) \ i = 2p^21s^2\ ^4P_{1/2} - 1s^22p^2\ ^2P_{1/2}$$

Fig. 3. Scaled excitation rate coefficients (Rc) for the six $2s2p(^{1,3}P)1s^2\ ^{2,4}P_J - 1s^22s^2\ ^2S_{1/2}$ lines of Li-like ions with $Z = 6, 8, 10, 12, 13, 16, 20, 22, 26, 28, 30, 36$ and 42 as function of the scaled electron temperature $1/\beta$ in units of Zs^2 (Ry), where $Zs = Z-2$.

(i) - (vi) ; the same transitions as in Fig.1

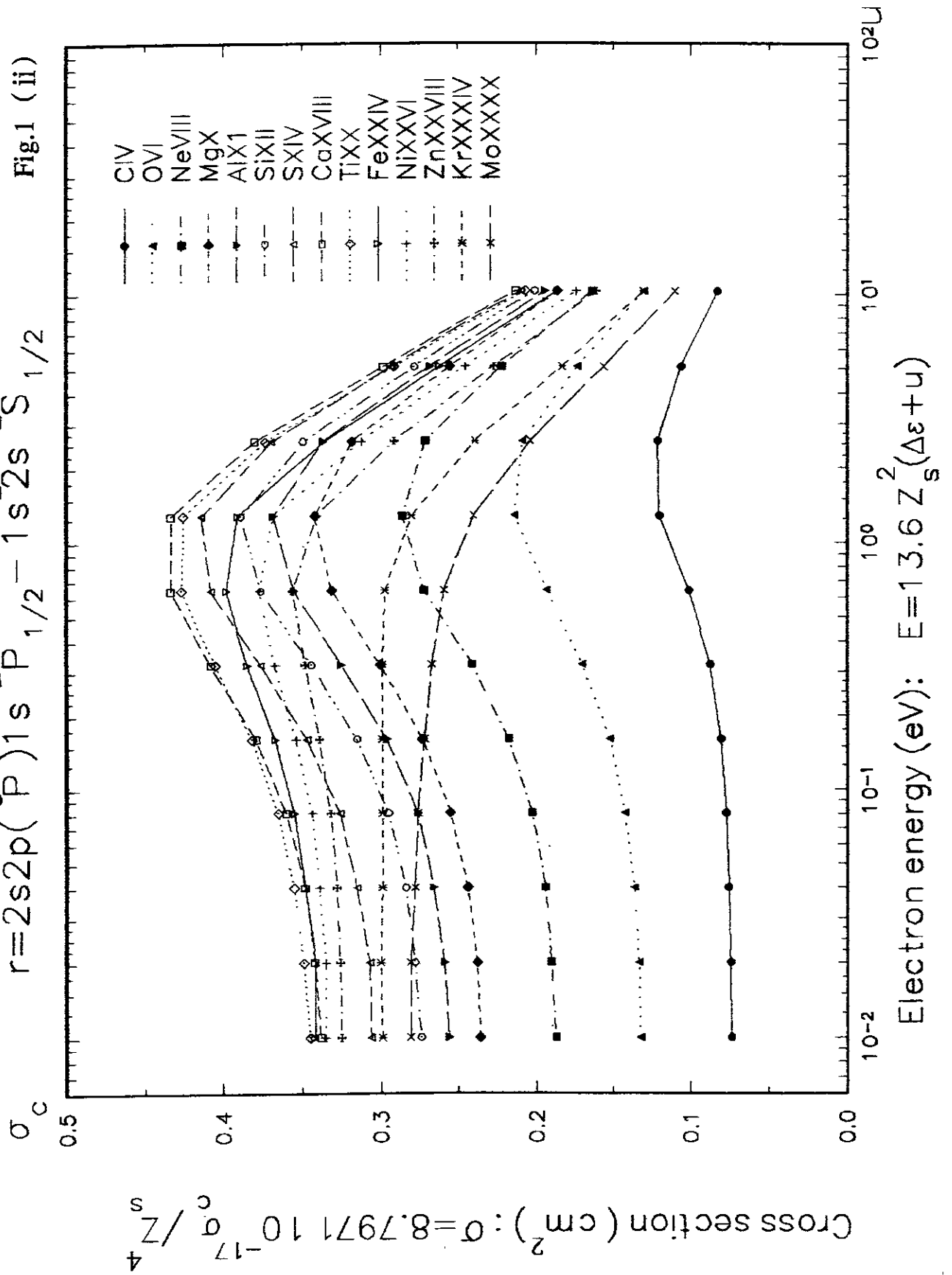
Fig.4. Scaled excitation rate coefficients (Rc) for the eight emissionlines $1s^22p - 1s2s^2$, $1s^22p - 1s2p^2$ of Li-like ions with $Z = 6, 8, 10, 12, 13, 16, 20, 22, 26, 28, 30, 36$ and 42 as function of the scaled electron temperature $1/\beta$ in units of Zs^2 (Ry), where $Zs = Z-2$.

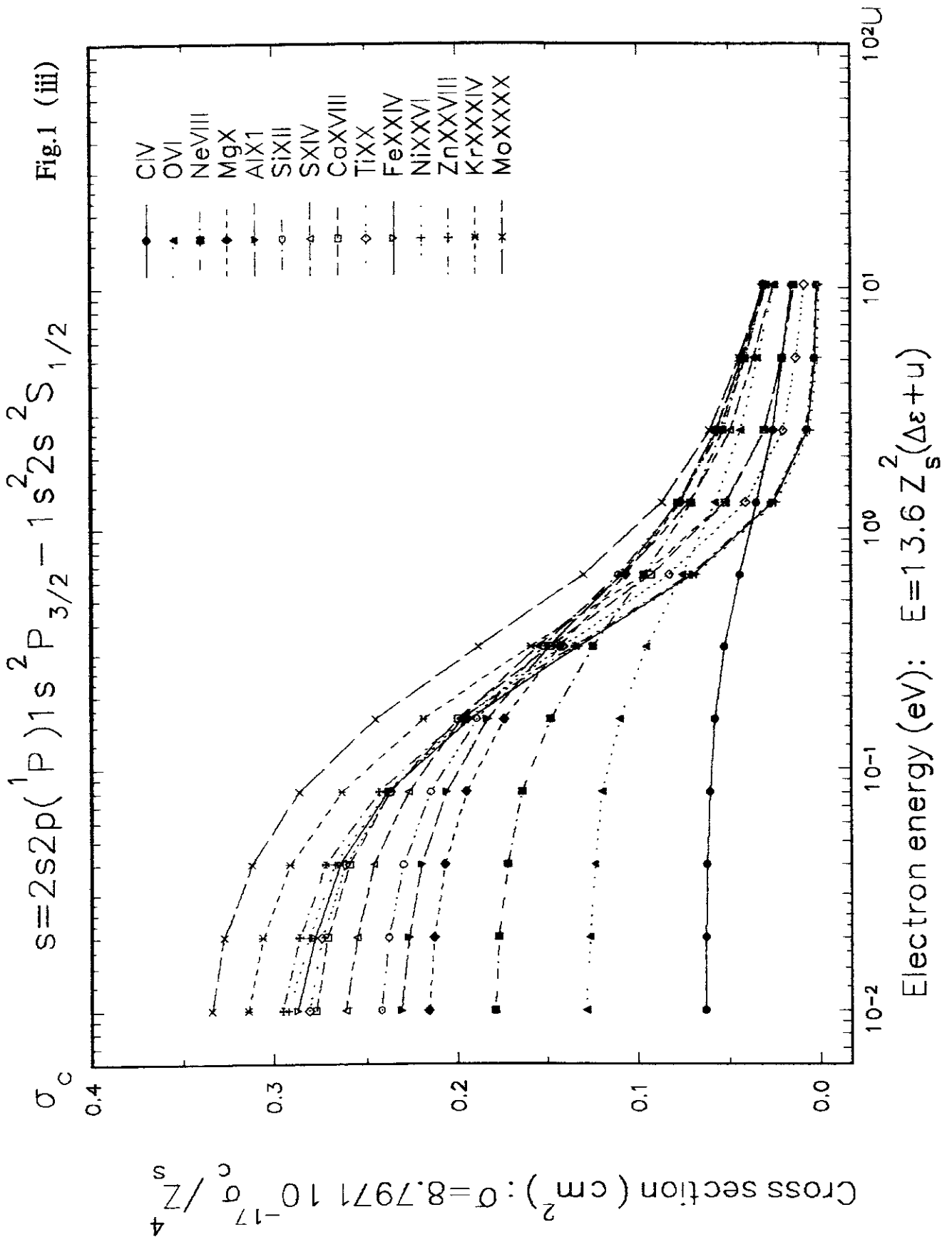
(i) - (viii) ; the same transitions as in Fig.2.



$$r=2s2p({}^3P)1s^2P_{1/2}-1s^2s^2S_{1/2}$$

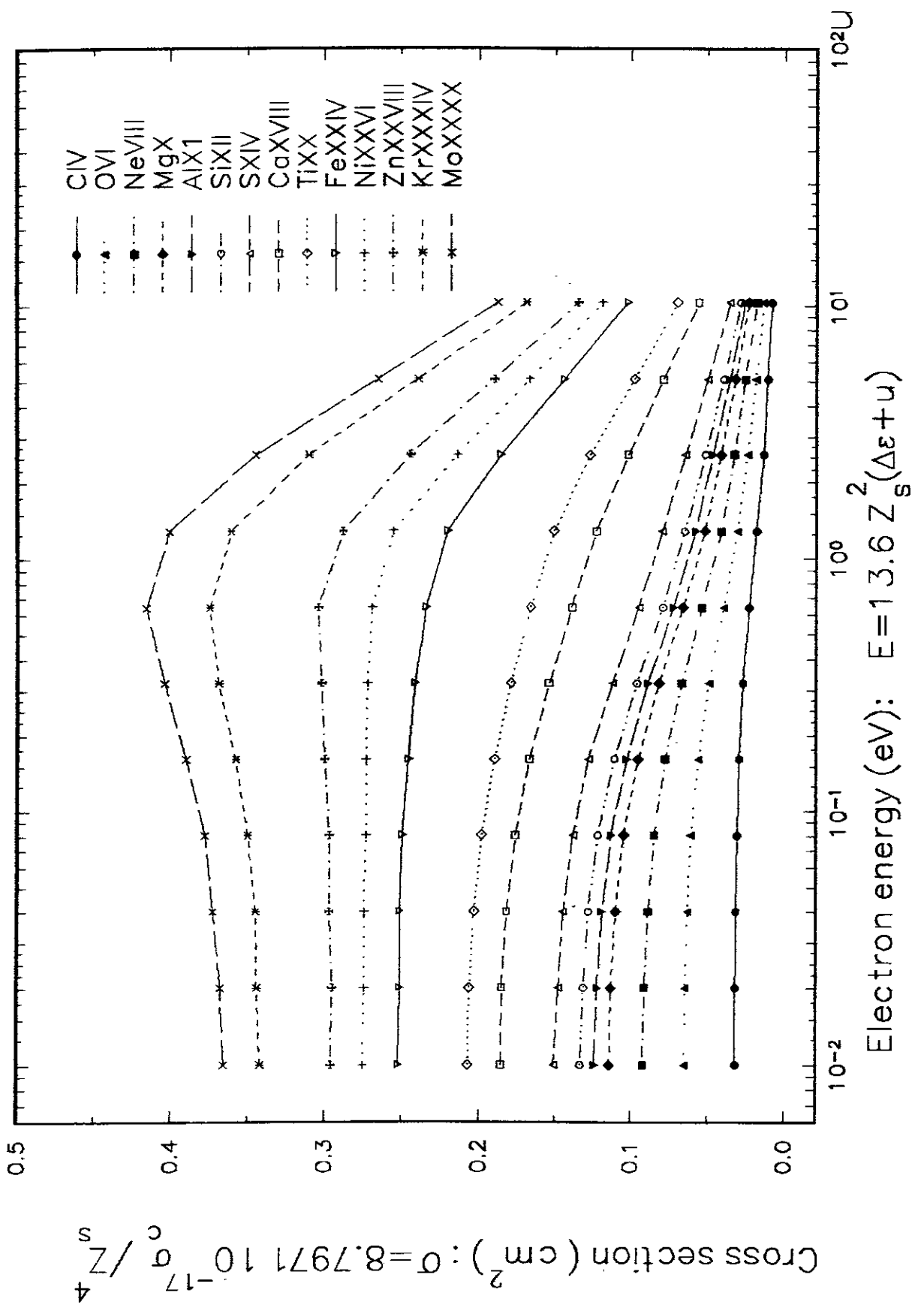
Fig.1 (ii)

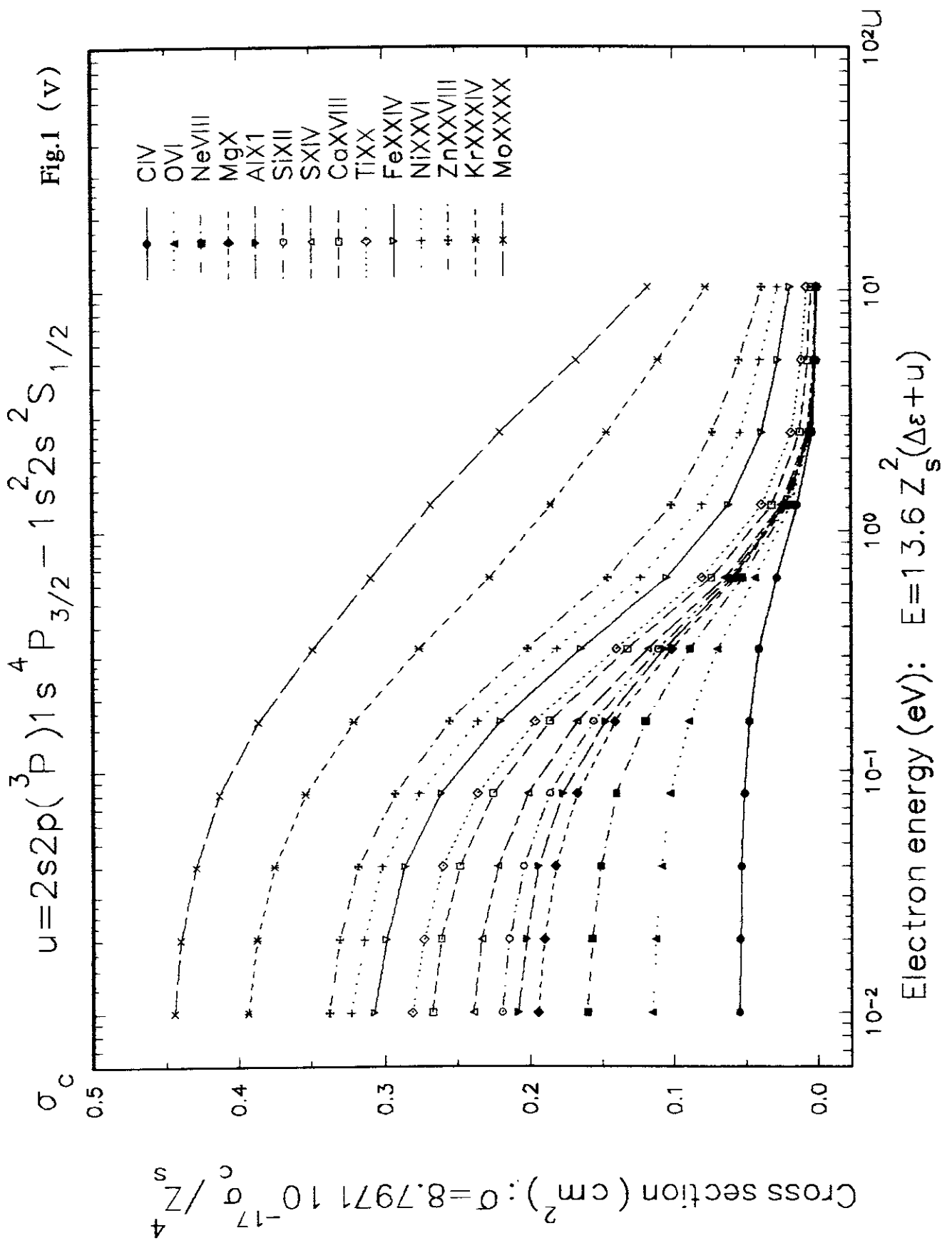




$$t=2s2p(^1P)1s^2P_{1/2}-1s^2s^2S_{1/2}$$

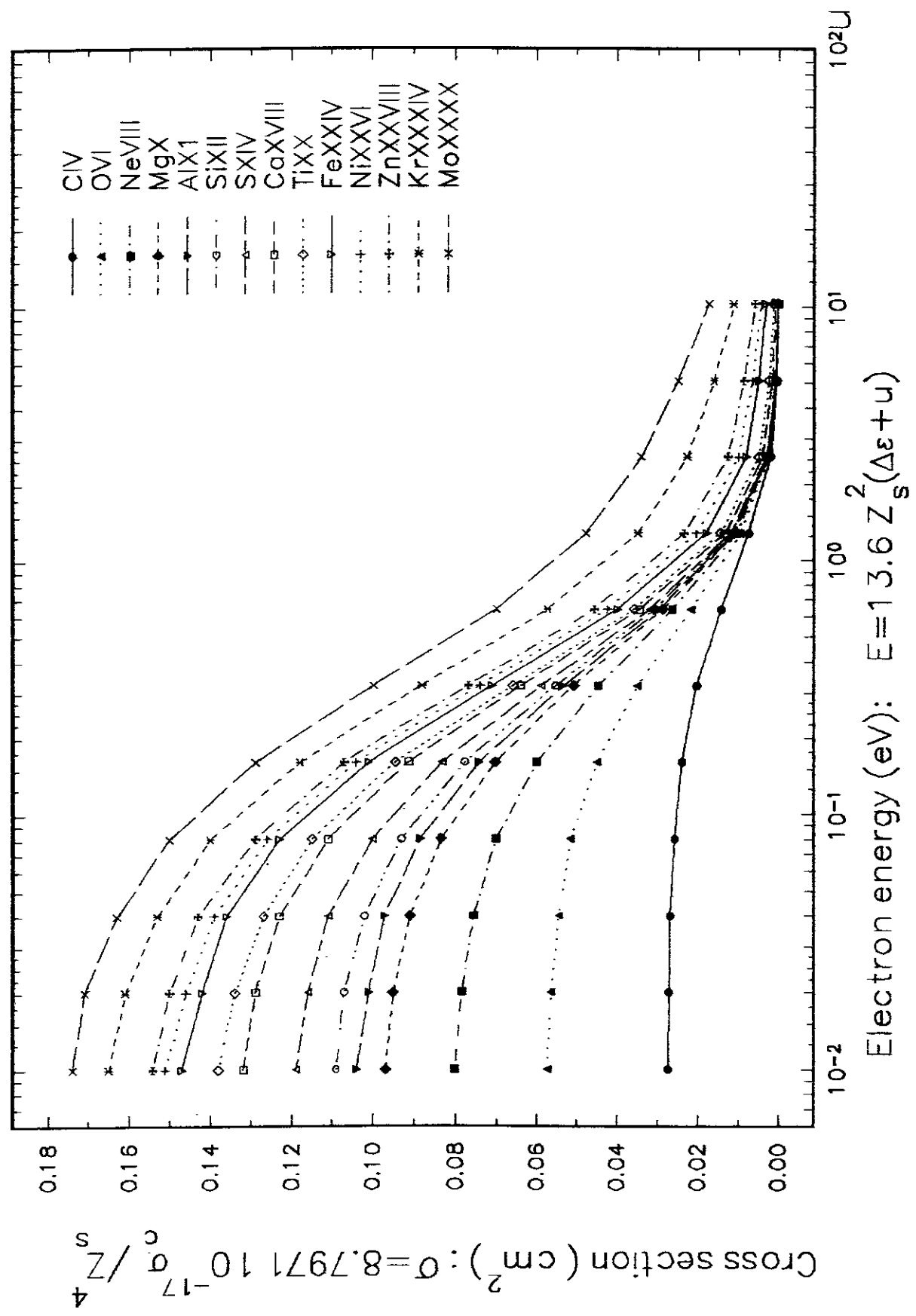
Fig.1 (iv)

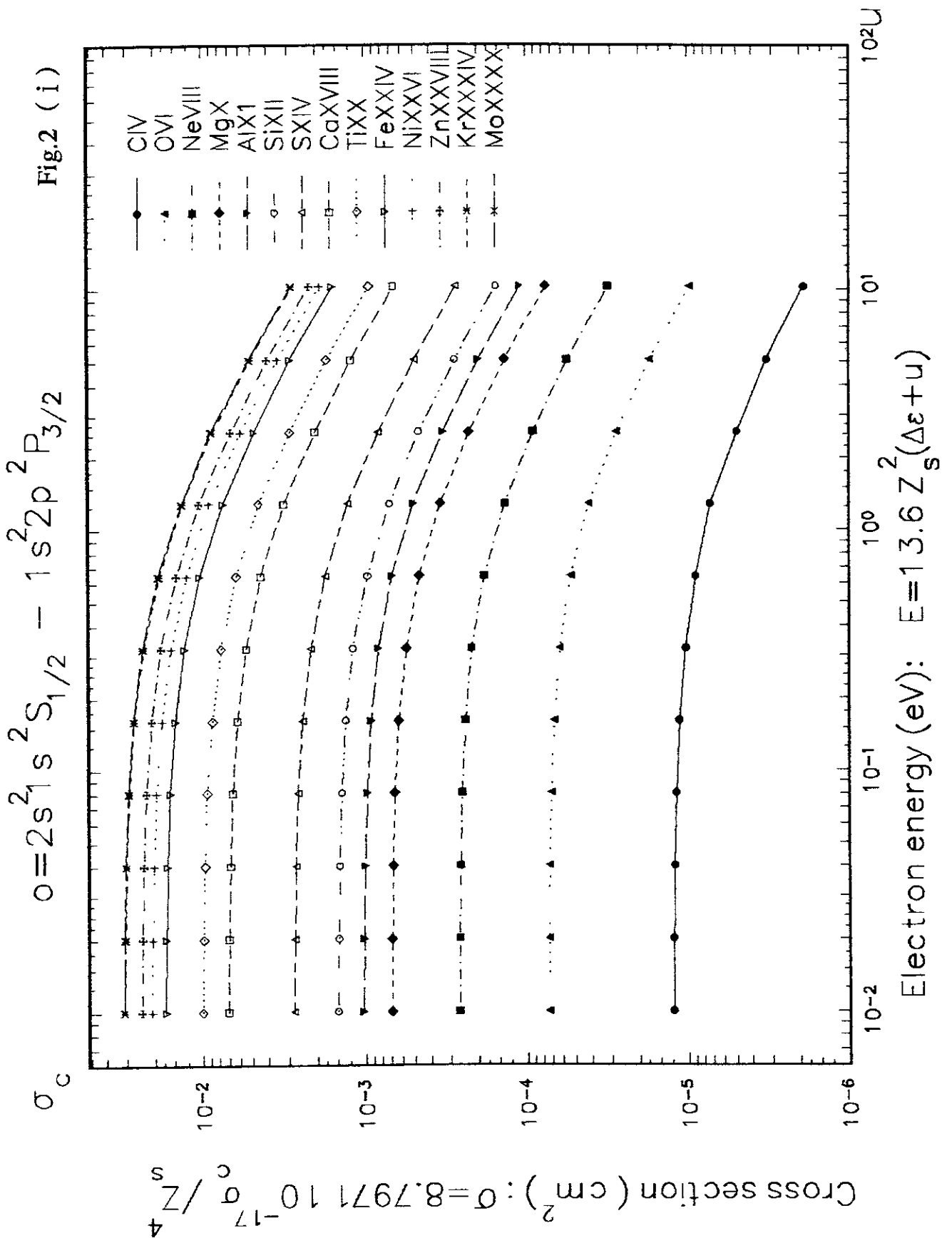




$$\sigma_c \quad v=2s2p(^3P)1s^4P_{1/2}-1s^22s^2S_{1/2}$$

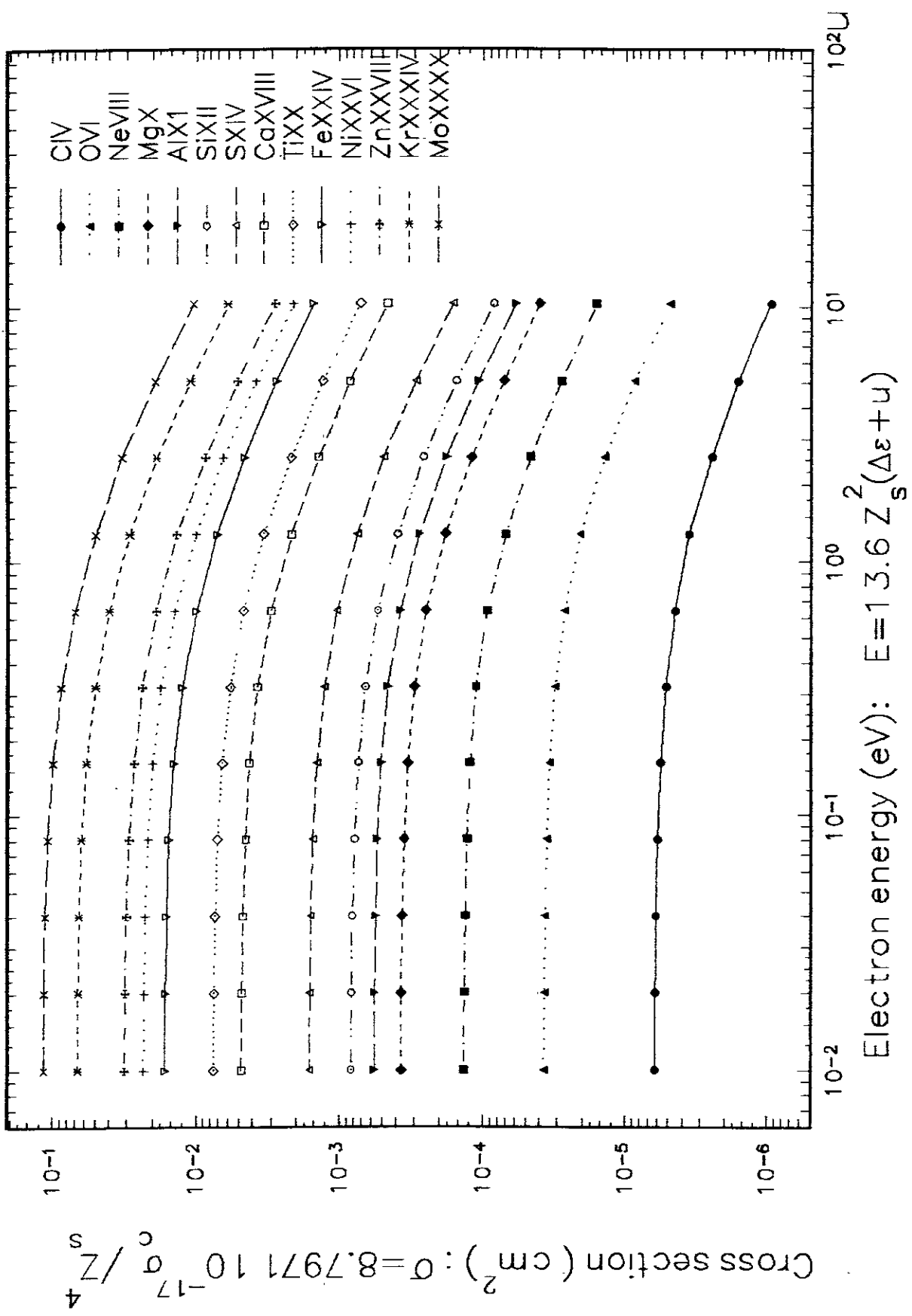
Fig.1 (vi)





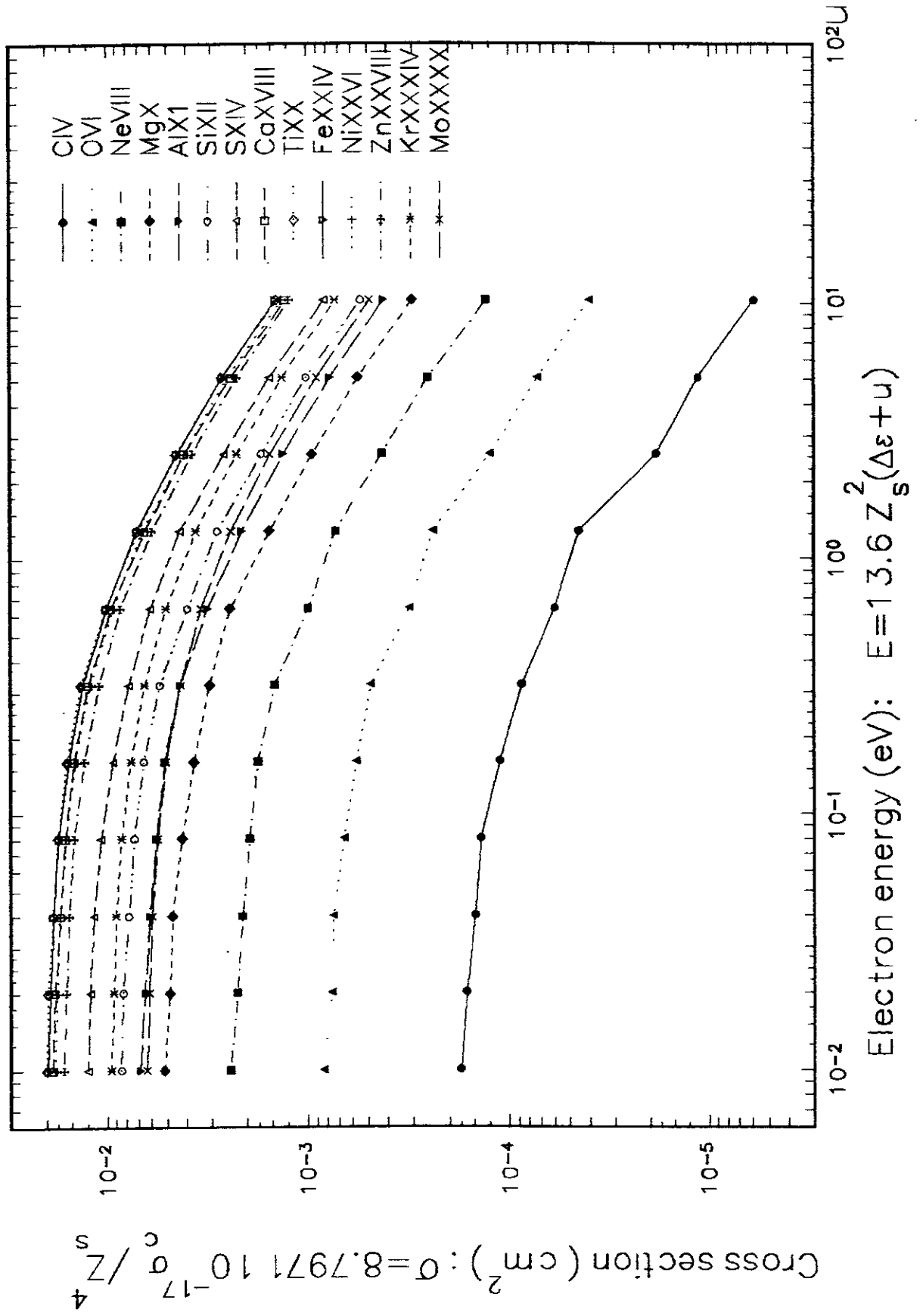
$$p = 2s^2 1s^2 S_{1/2} - 1s^2 2p^2 P_{1/2}$$

Fig.2 (ii)



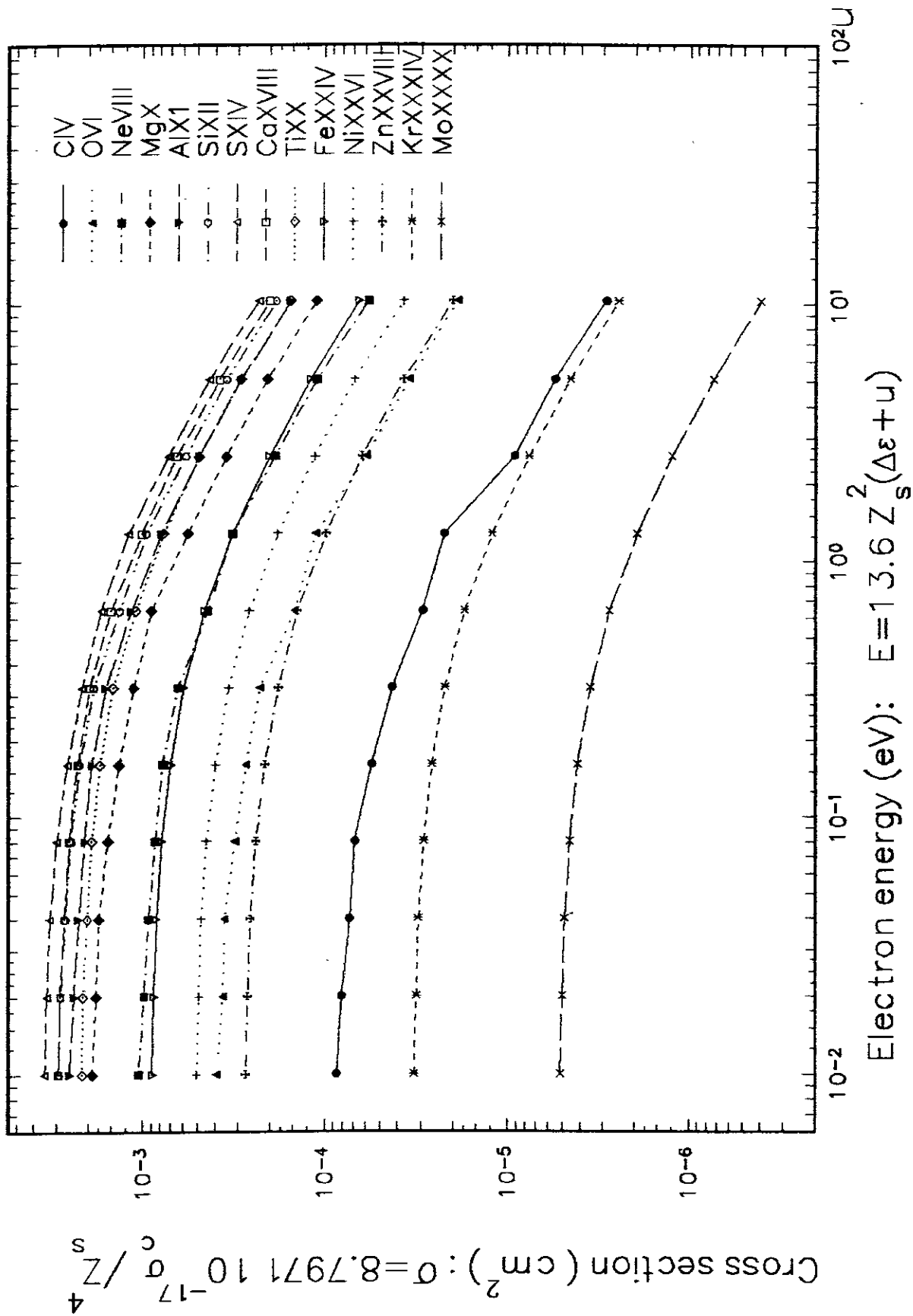
$$m=2p^2 1s^2 S_{1/2} - 1s^2 2p^2 P_{3/2}$$

Fig.2 (iii)



$$n=2p^2 1s^2 S_{1/2} - 1s^2 2p^2 P_{1/2}$$

Fig.2 (iv)



$$c = 2p^2 1s^2 P_{1/2} - 1s^2 2p^2 P_{3/2}$$

Fig.2 (v)

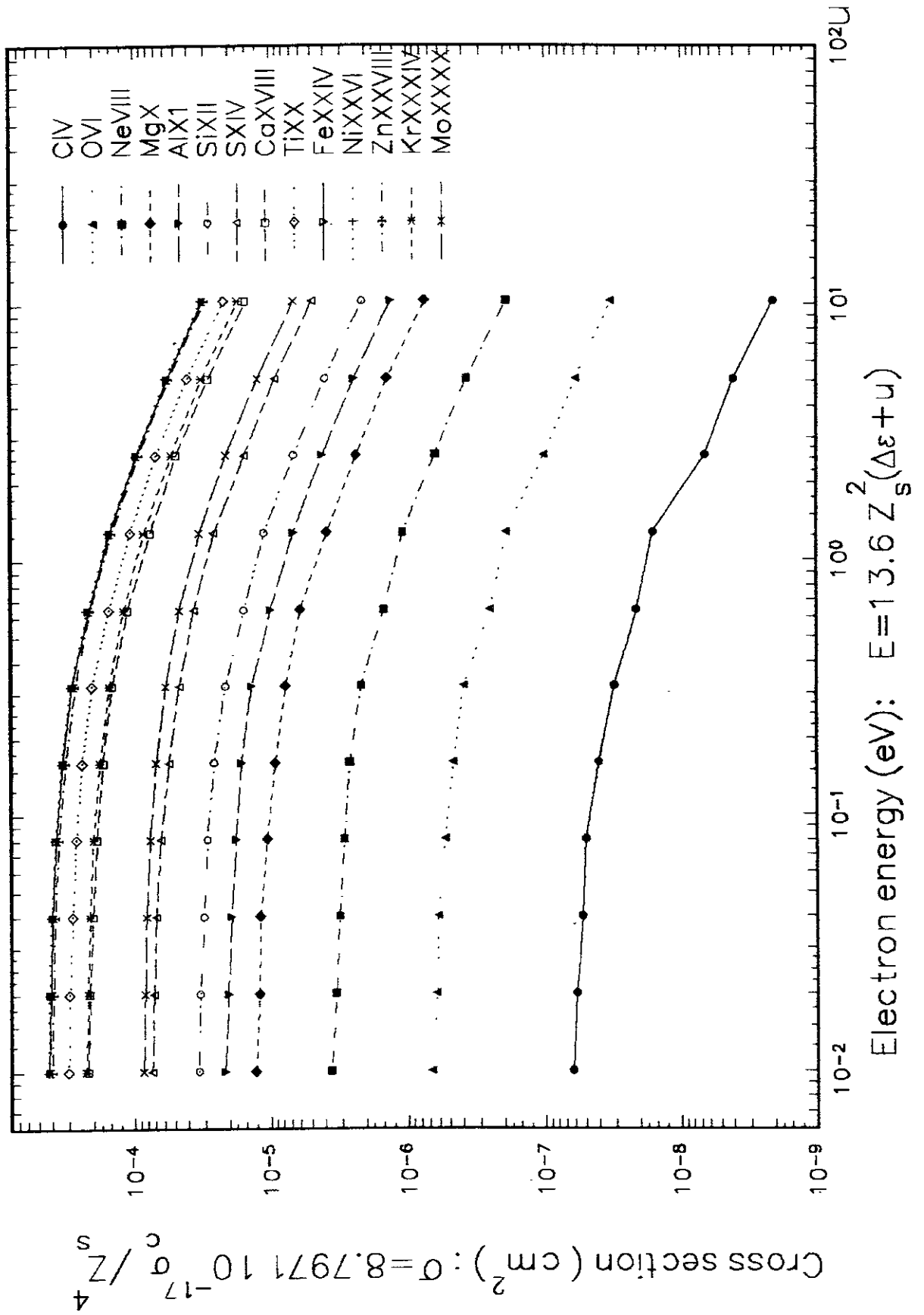
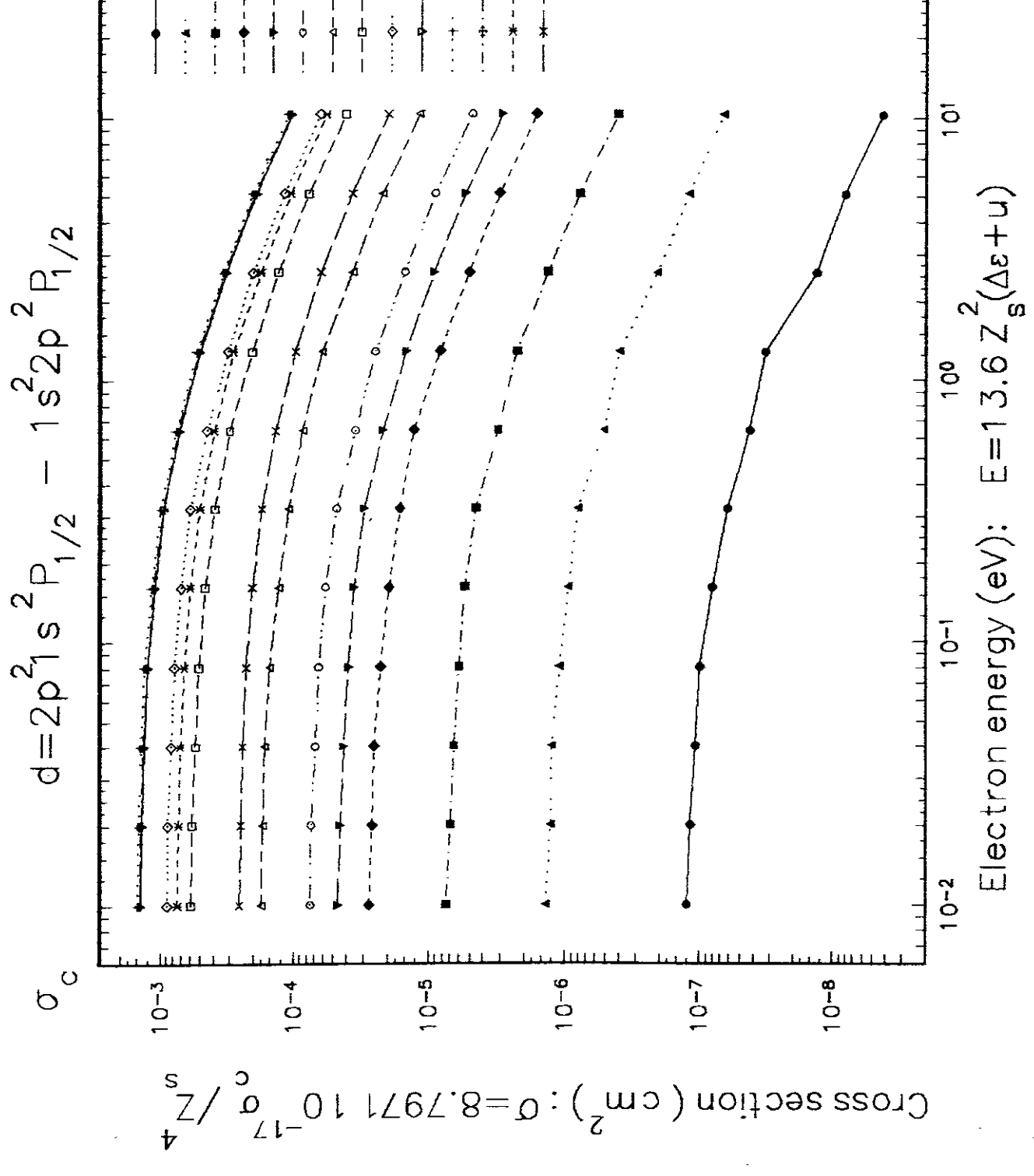
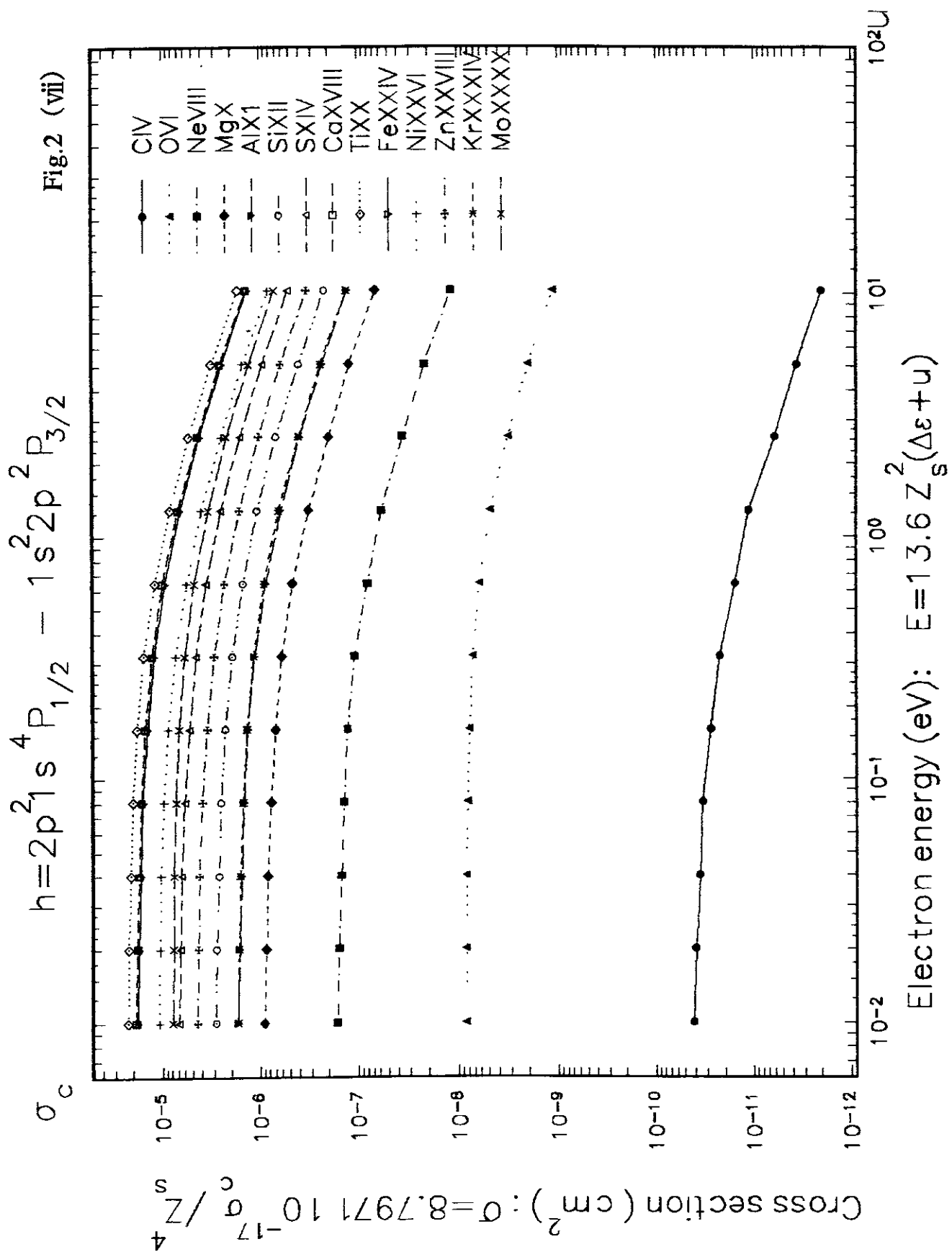


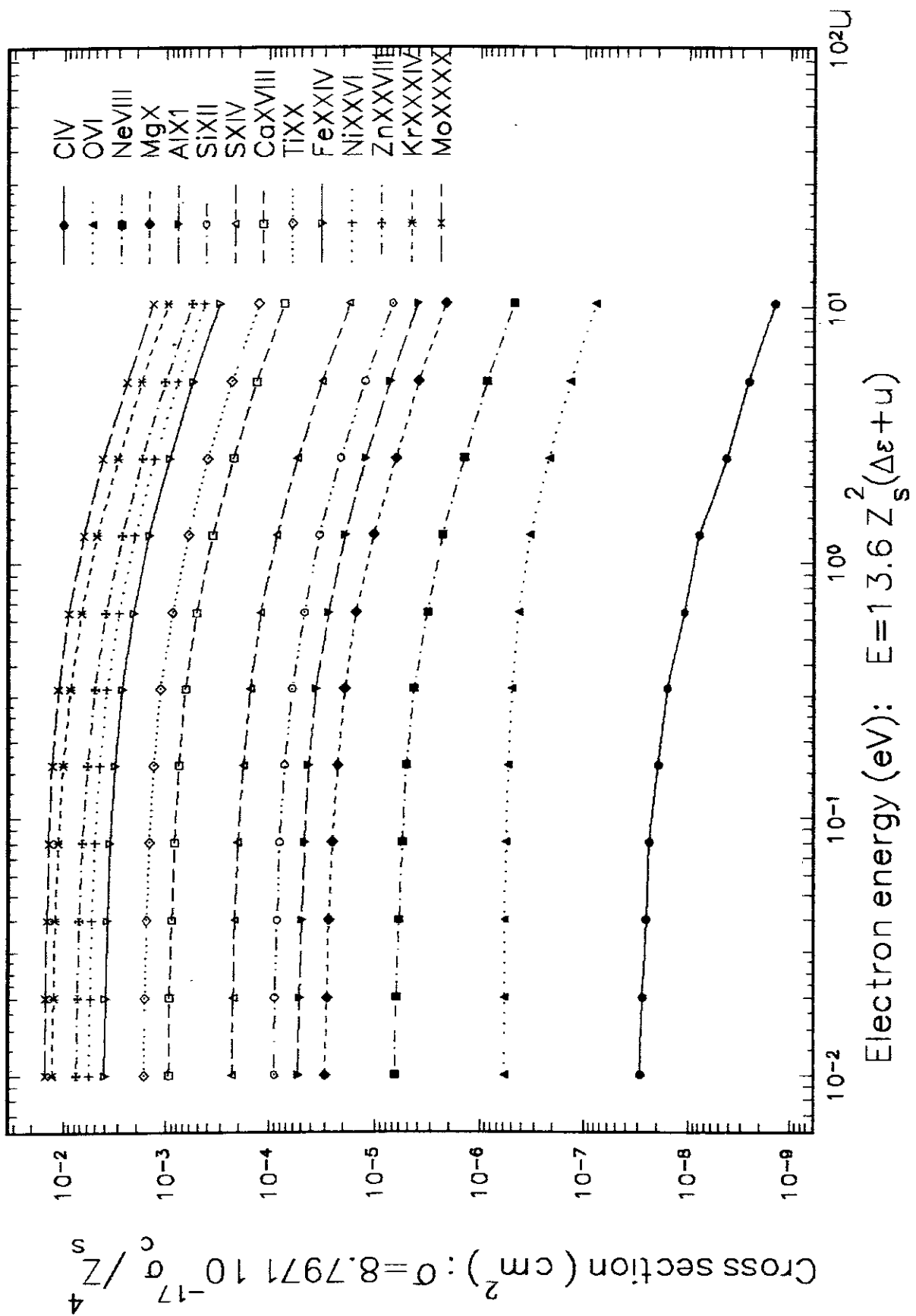
Fig.2 (vi)





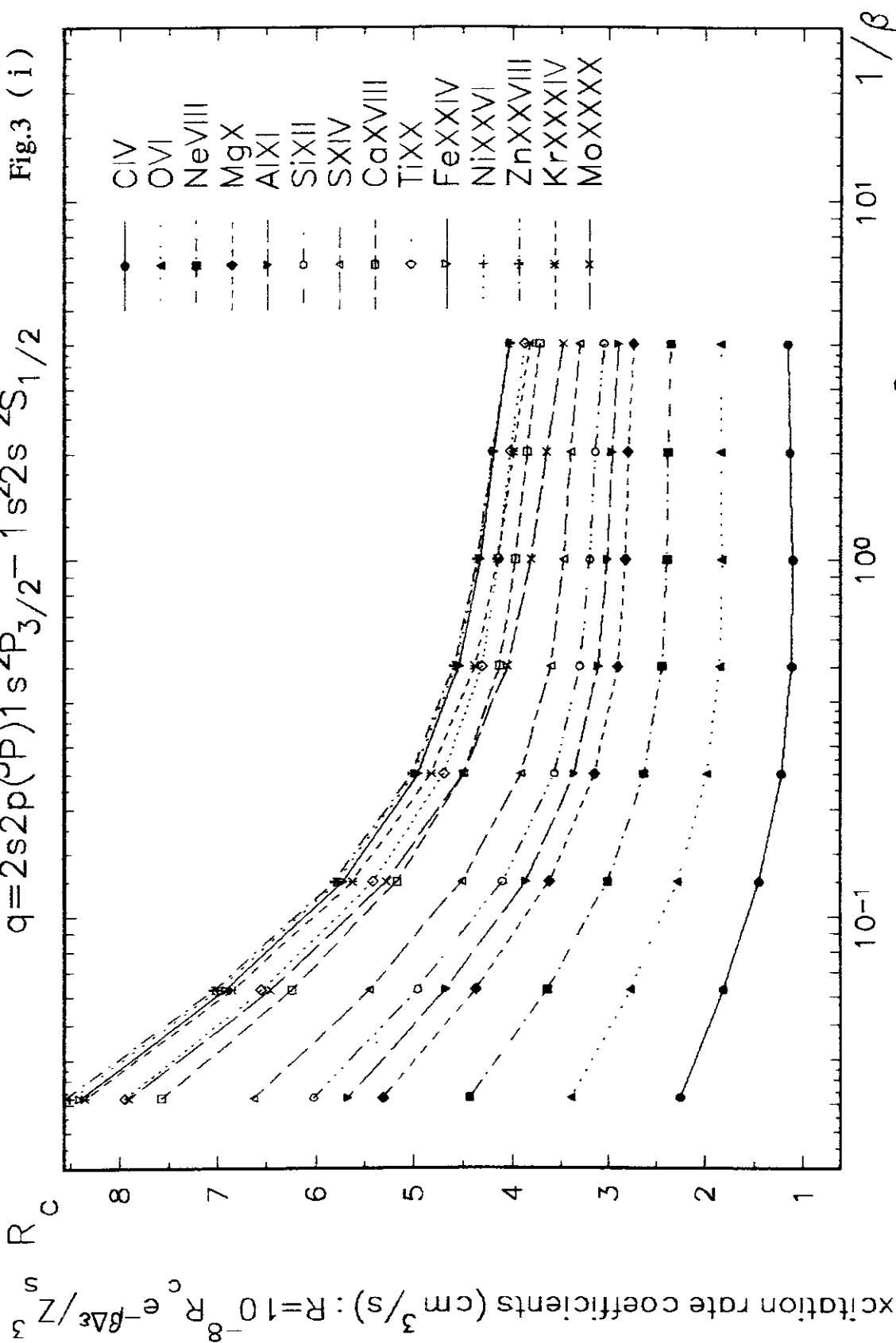
$$i=2p^2 1s^4 P_{1/2} - 1s^2 2p^2 P_{1/2}$$

Fig.2 (viii)



$$q = 2s2p(^3P)1s^2P_{3/2} - 1s^2s^2S_{1/2}$$

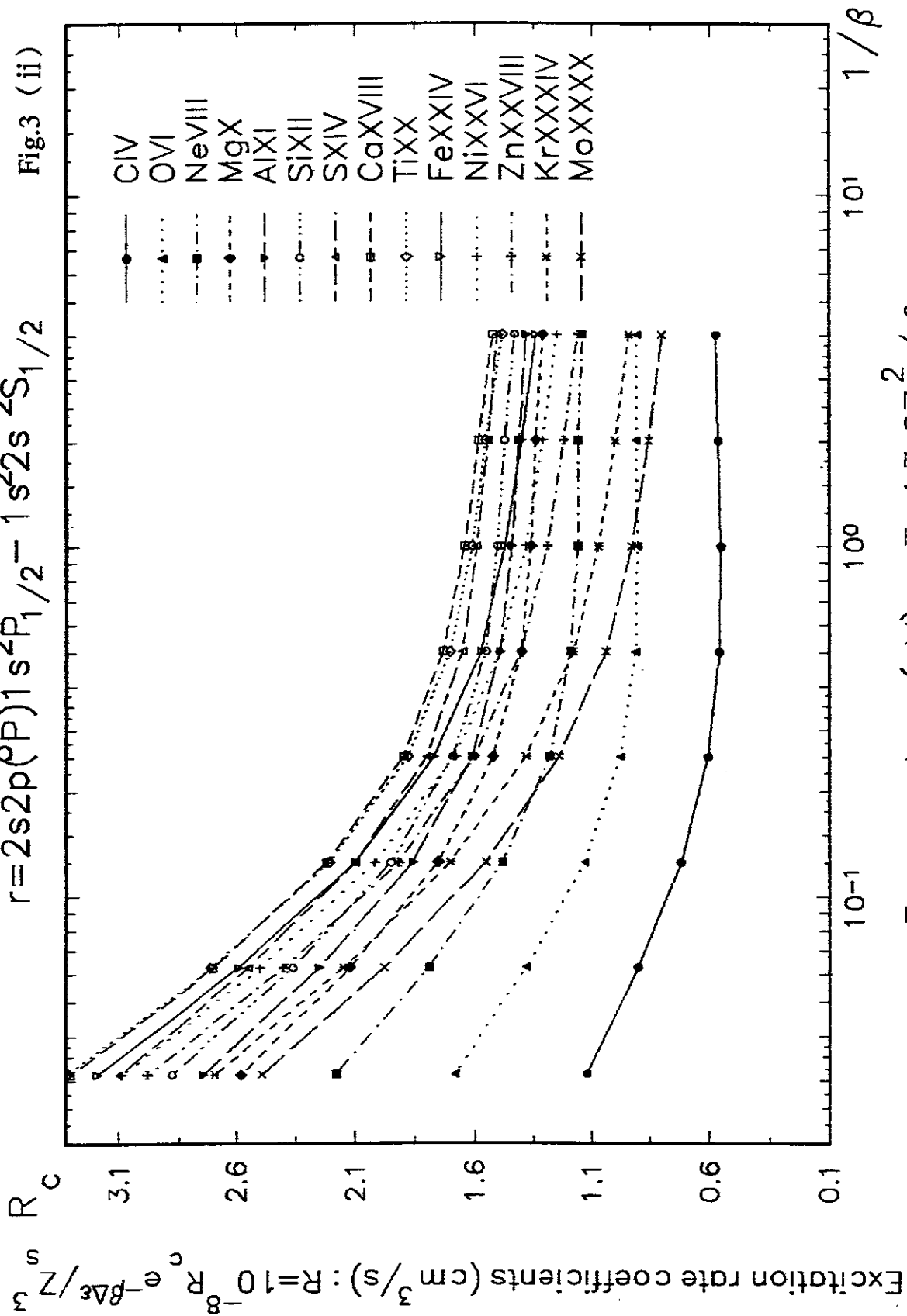
Fig.3 (i)



Temperature (eV) : $T = 13.6Z^2 / \beta$

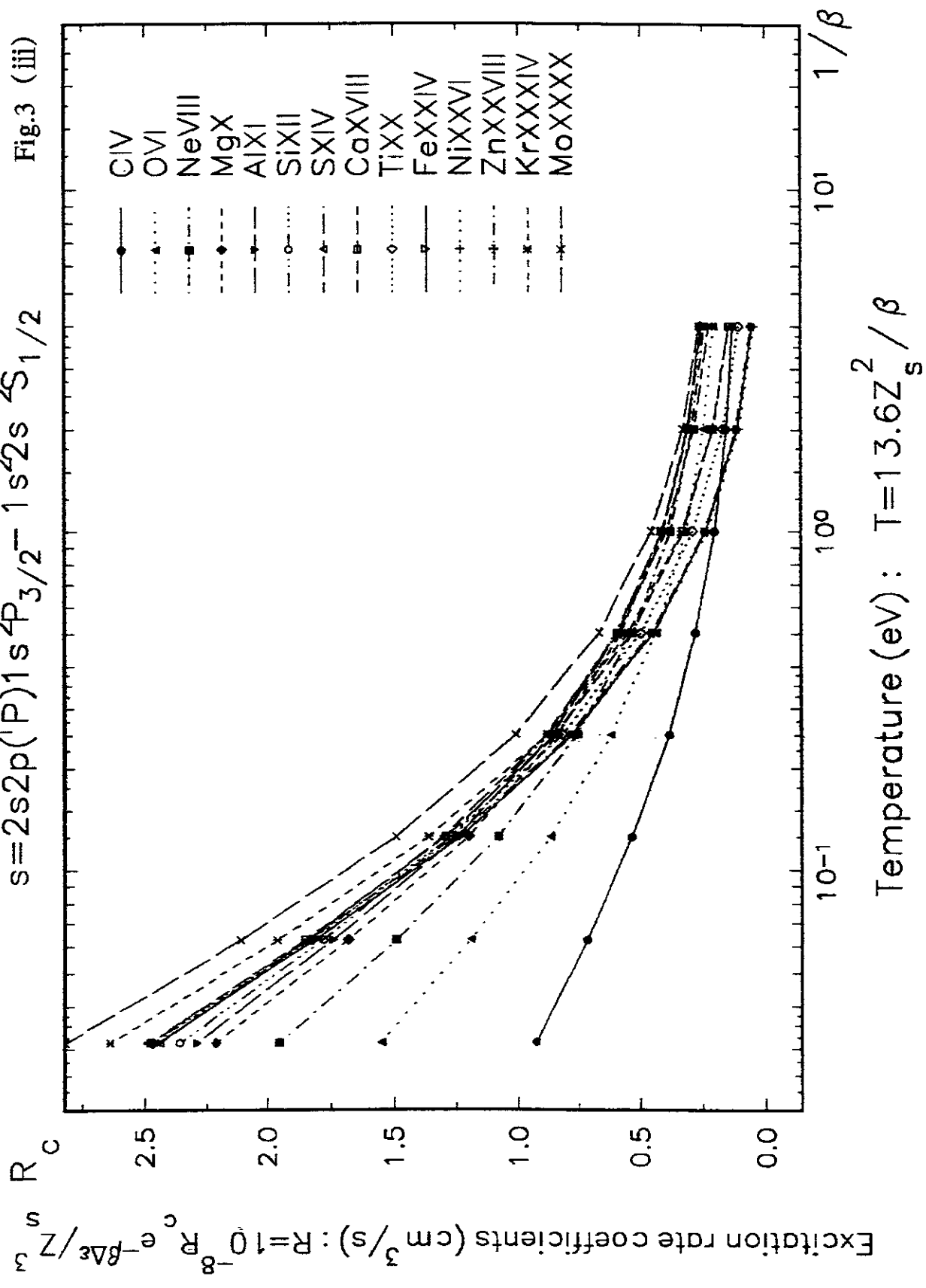
$$r = 2s2p(\bar{3}P)1s^2P_{1/2} - 1s^22s^2S_{1/2}$$

Fig.3 (ii)



$$s=2s2p(1P)1s^2P_{3/2} - 1s^2s^2S_{1/2}$$

Fig.3 (iii)



$$t = 2s2p(P)1s^2P_{1/2} - 1s^2s^2S_{1/2}$$

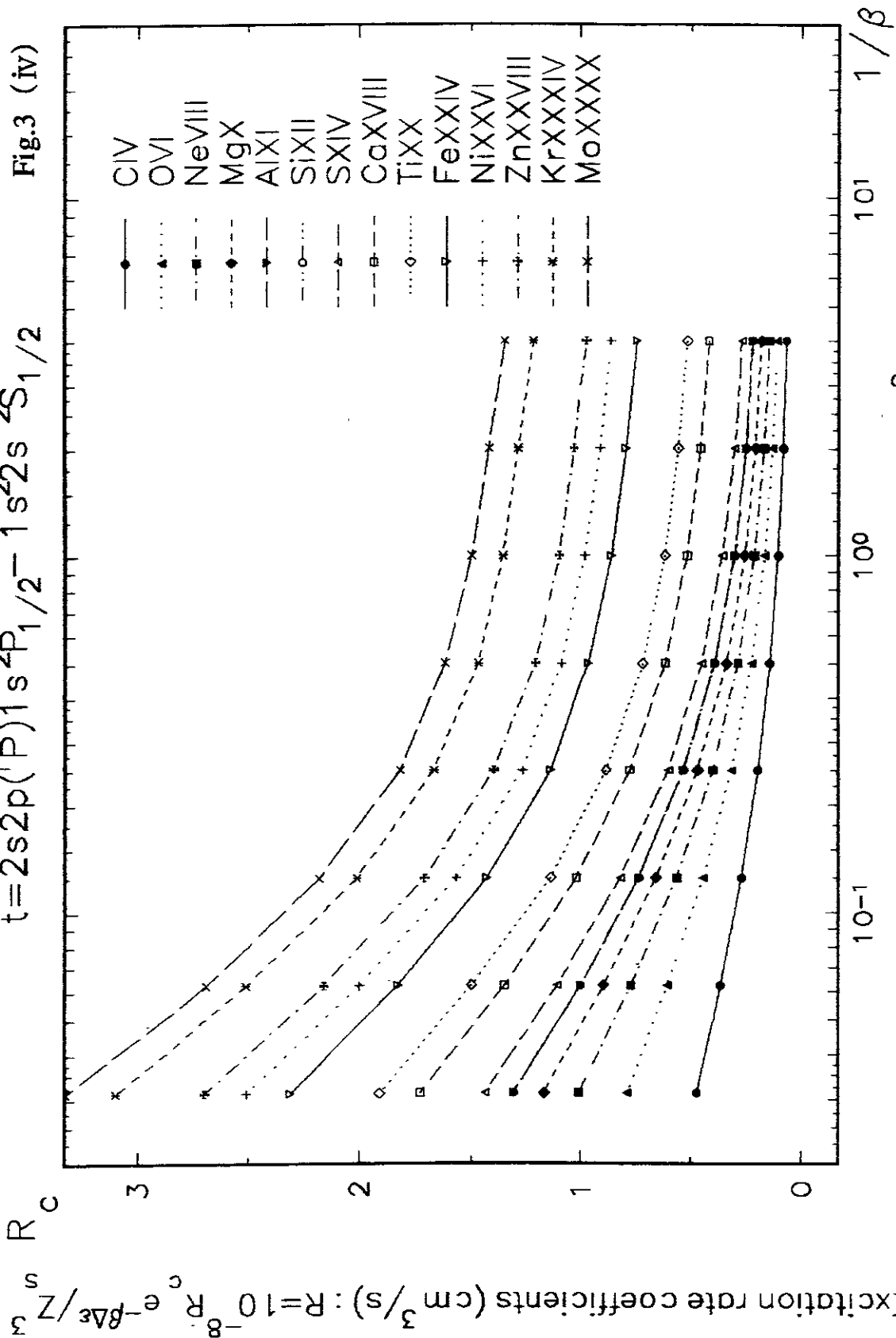
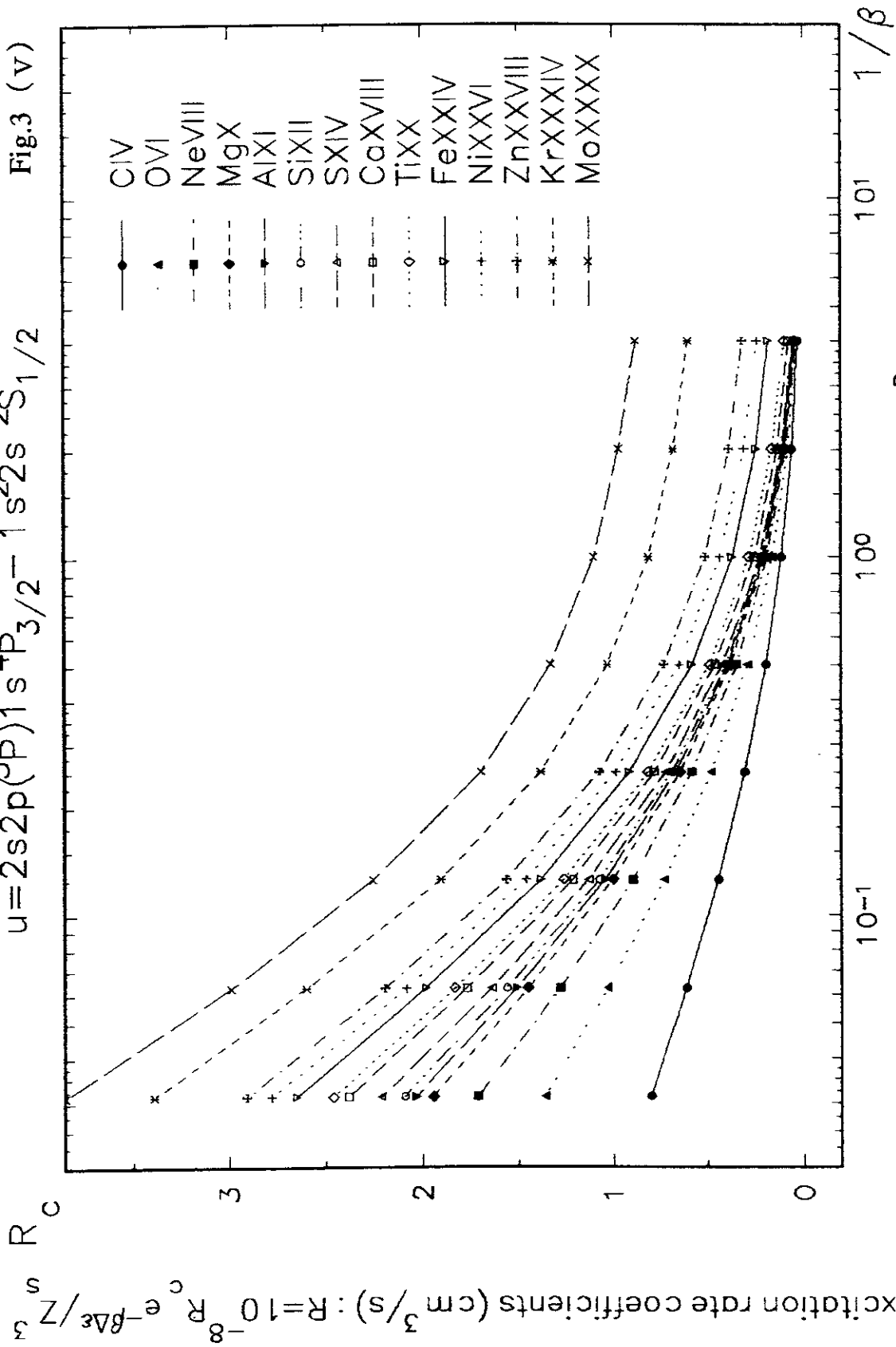


Fig.3 (iv)

Temperature (eV) : $T = 13.6 Z_s^2 / \beta$

$$u = 2s2p(^3P)1s^4P_{3/2} - 1s^22s^2S_{1/2}$$

Fig.3 (v)



Temperature (eV) : $T = 13.6 Z_s^2 / \beta$

$$v=2s2p(^3P)1s^4P_{1/2} - 1s^22s^2S_{1/2}$$

Excitation rate coefficients (cm^3/s): $R=10^{-8} R_c e^{-\beta \Delta \epsilon / Z^2}$

R_c

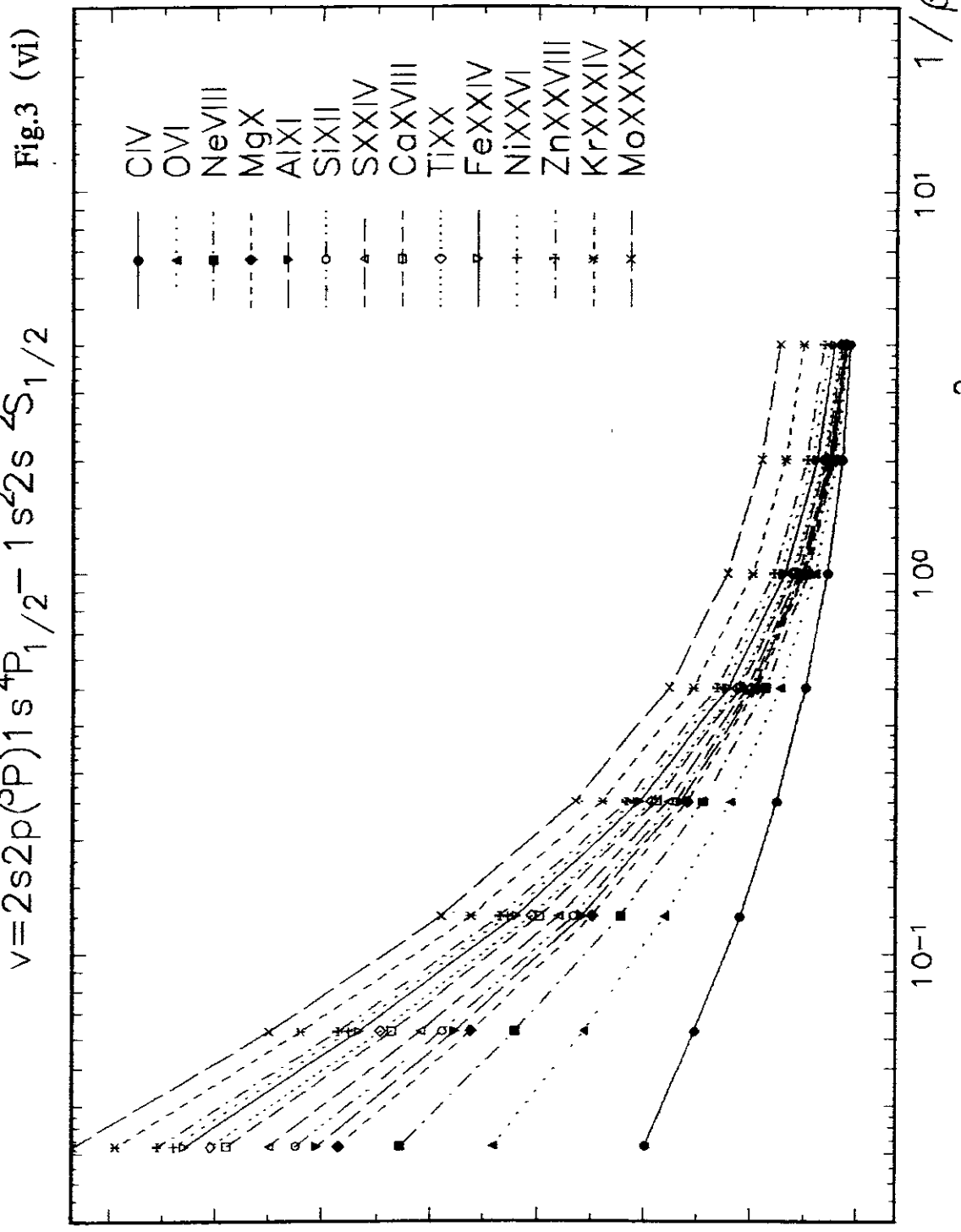
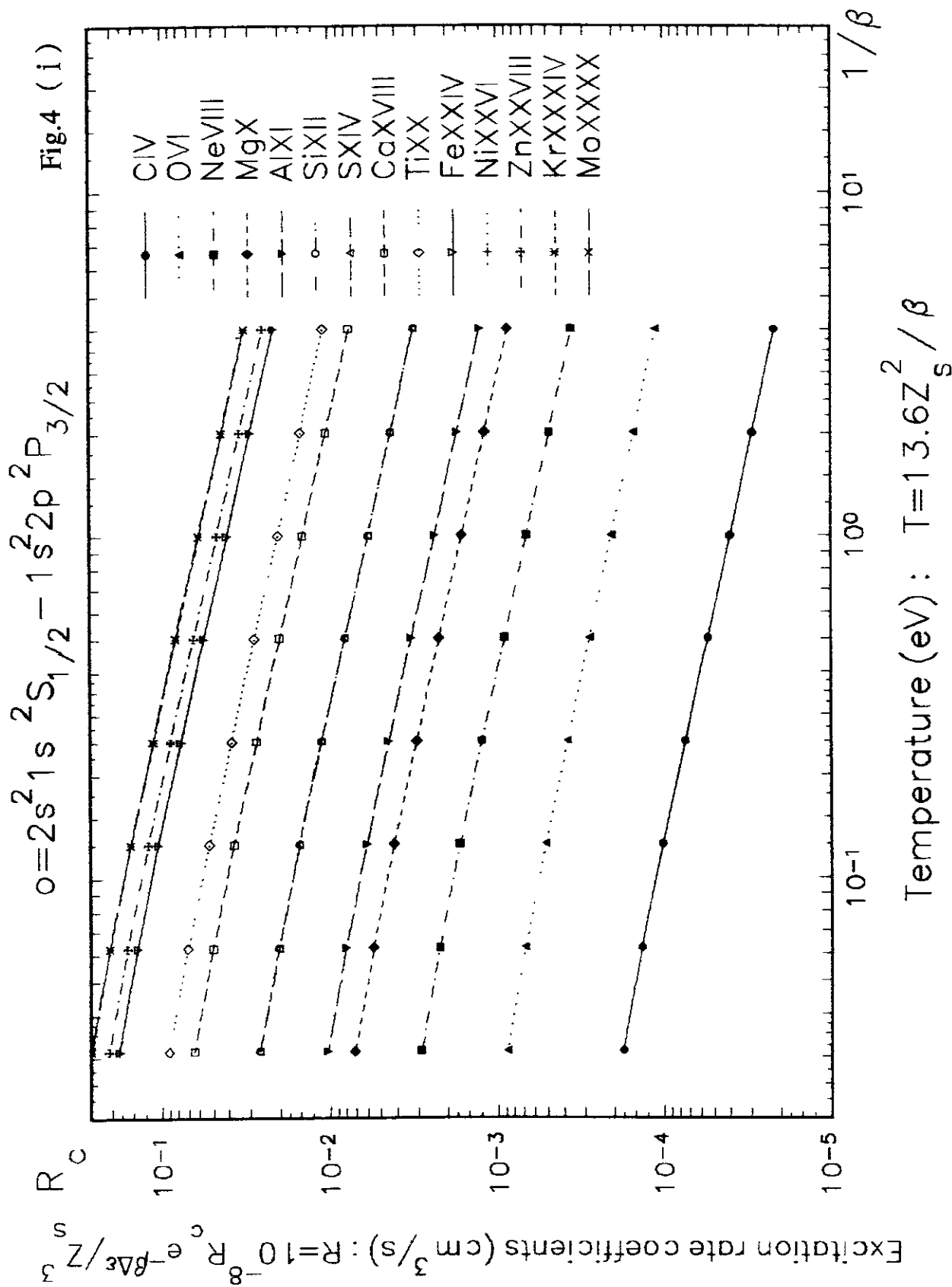


Fig.3 (vi)

Temperature (eV): $T=13.6Z^2 / \beta$



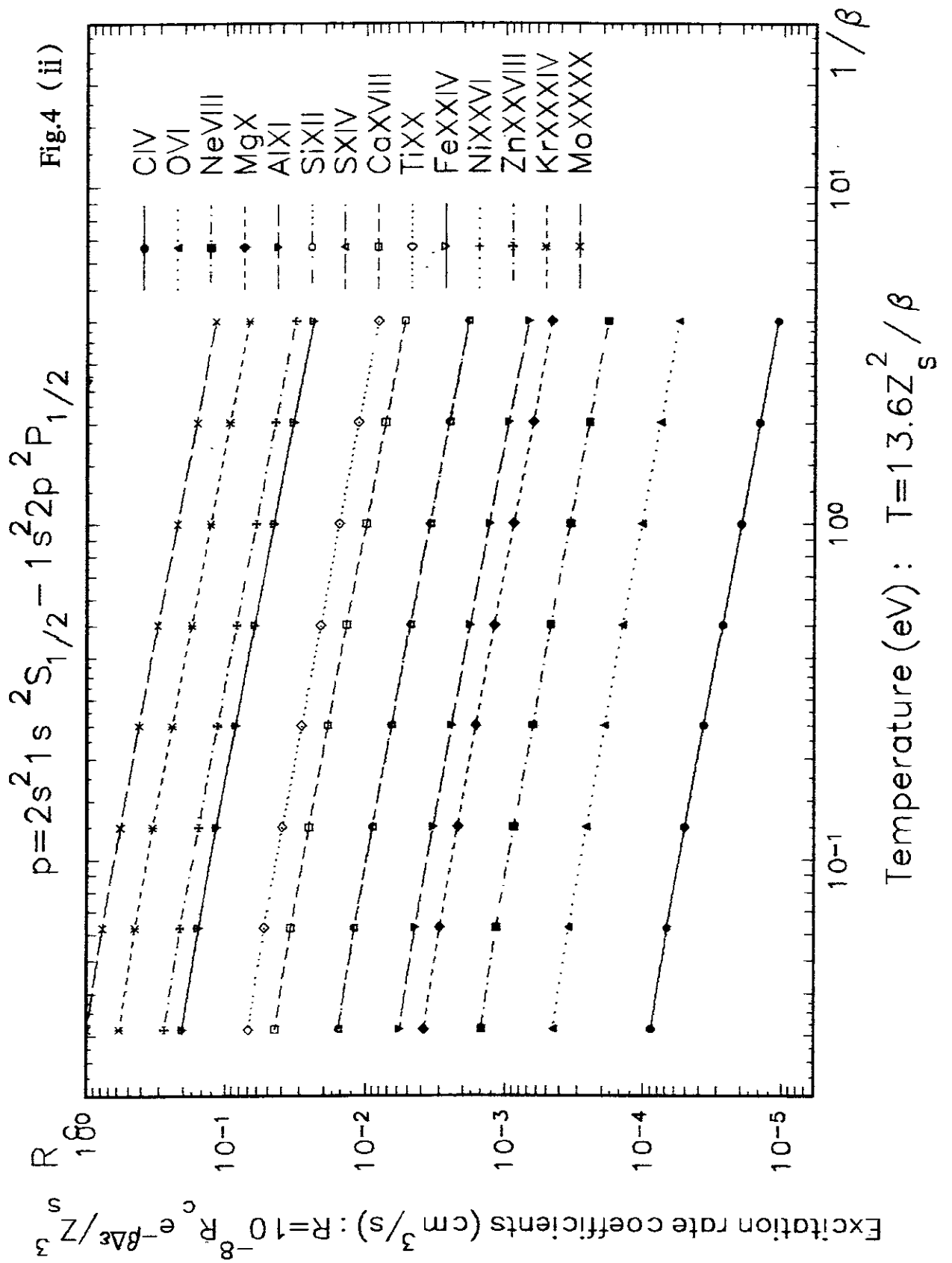
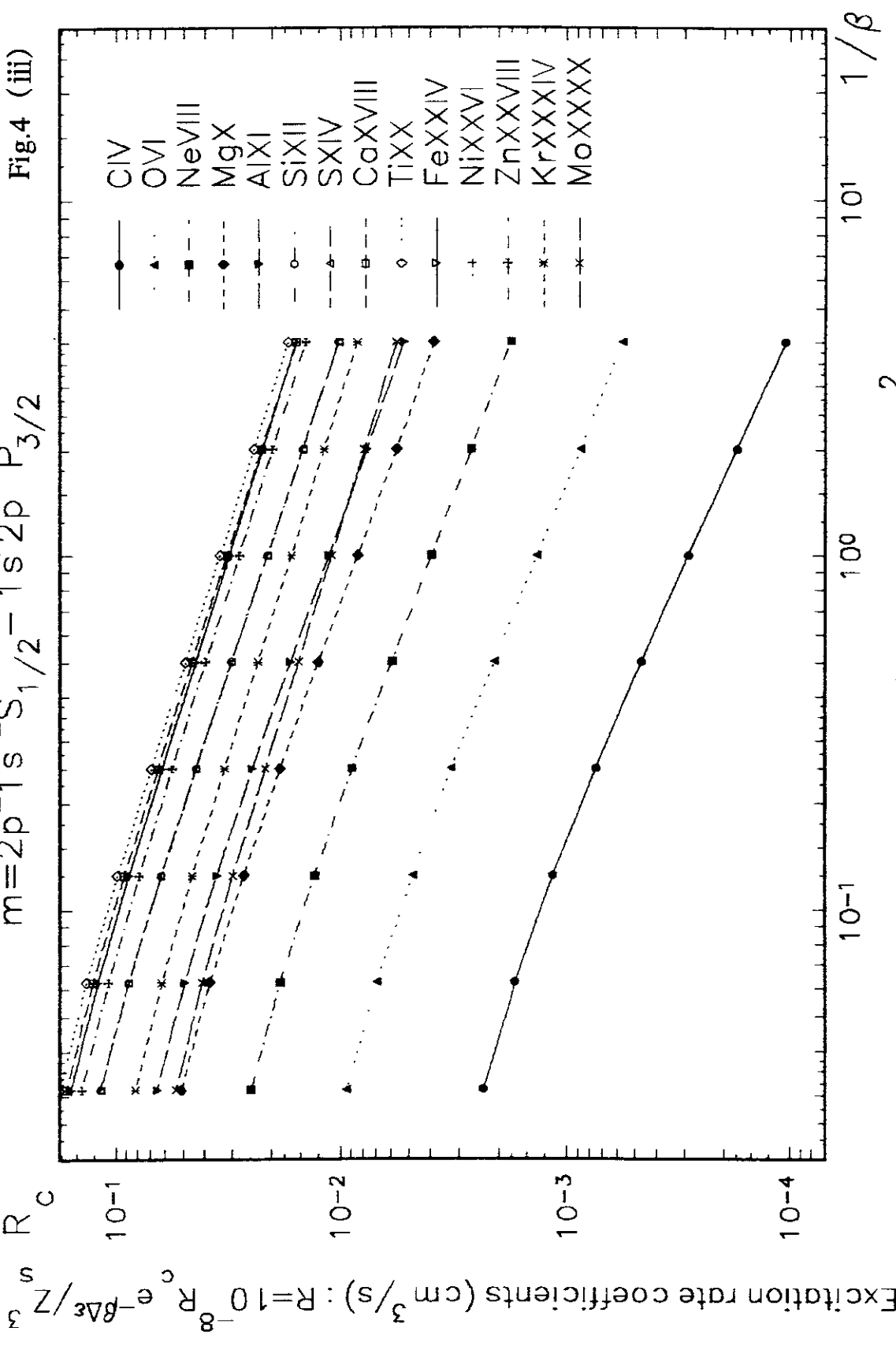
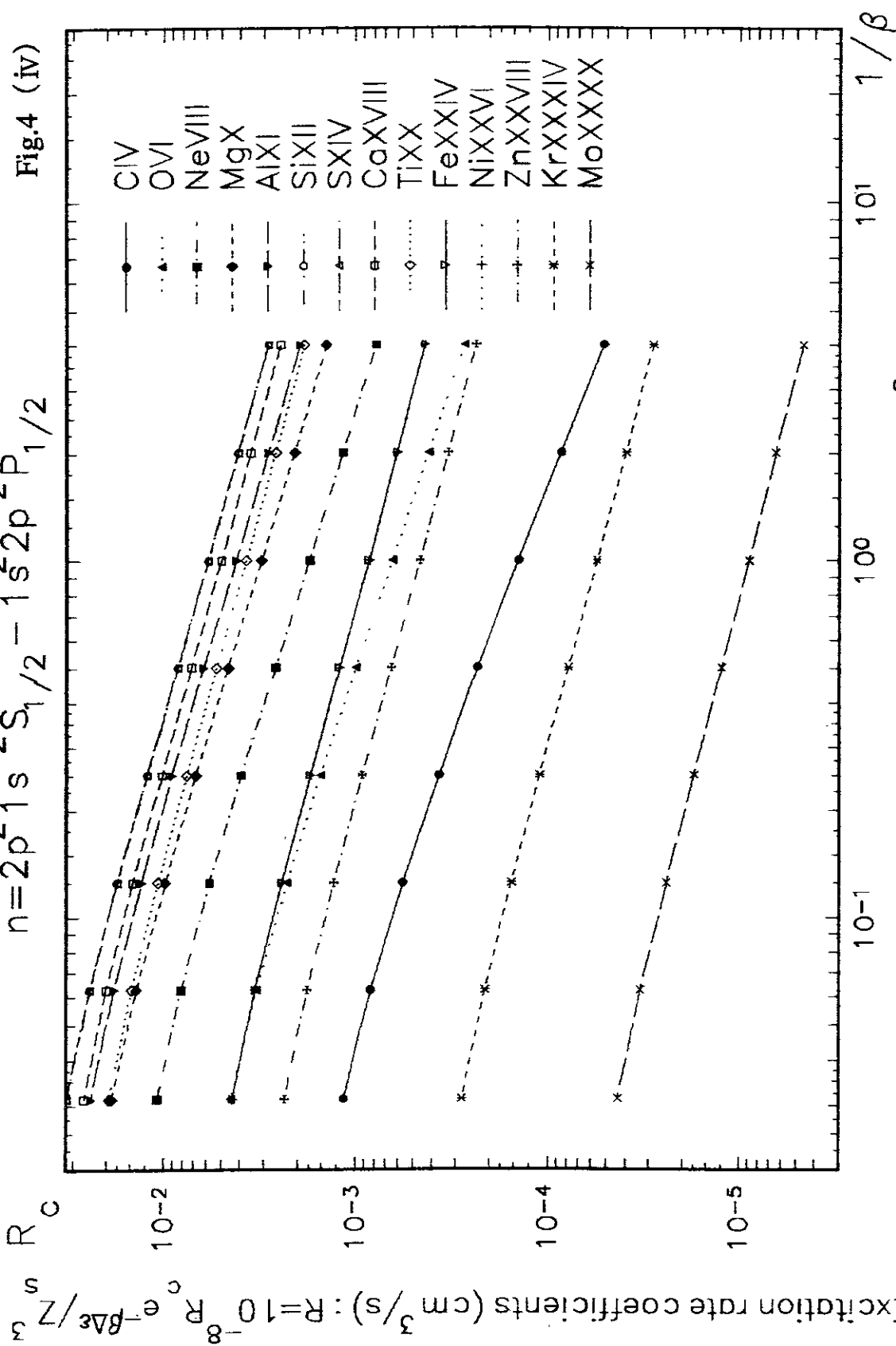


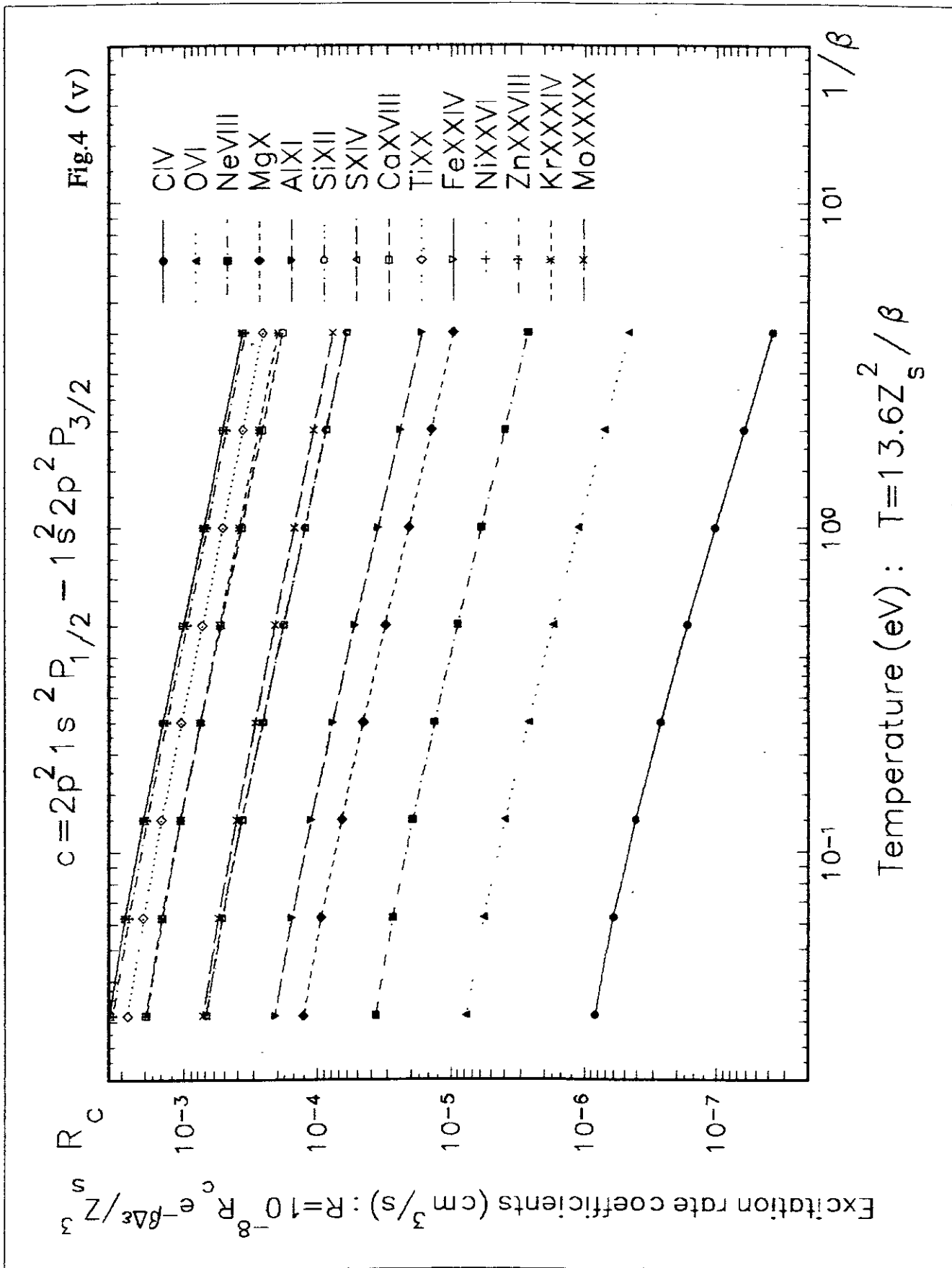
Fig.4 (iii)

$$m=2p^2 1s^2 S_{1/2} - 1s^2 2p^2 P_{3/2}$$



$$n=2p^2 1s^2 S_{1/2} - 1s^2 2p^2 P_{1/2}$$



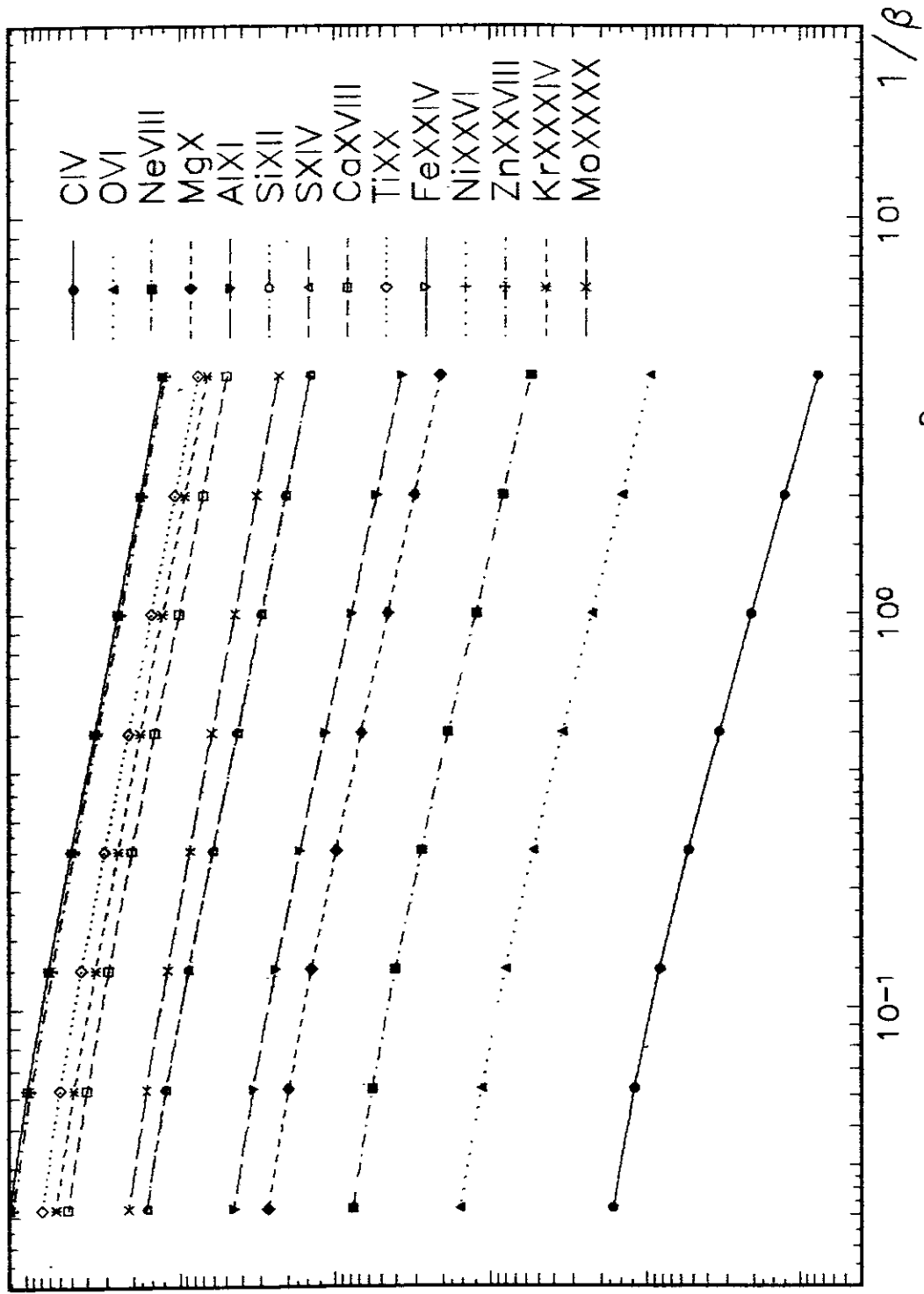


$$d=2p^2 1s^2 P_{1/2} - 1s^2 2p^2 P_{1/2}$$

Excitation rate coefficients (cm^3/s): $R=10^{-8} R_c e^{-\beta \Delta \epsilon / Z_s^2}$

R_c 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7}

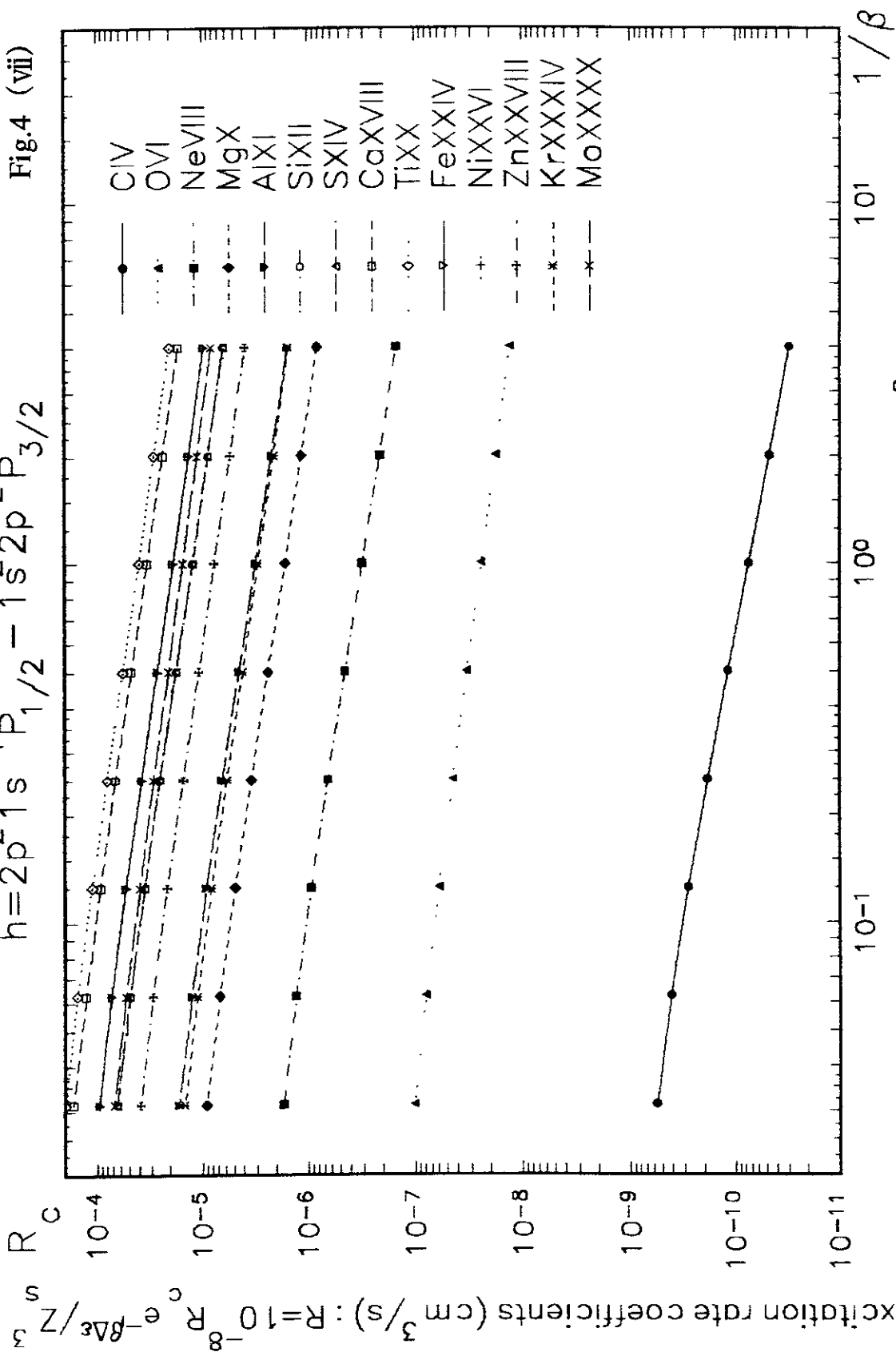
Fig.4 (vi)



Temperature (eV): $T=13.6Z_s^2 / \beta$

$$h = 2p^2 1s^4 P_{1/2} - 1s^2 2p^2 P_{3/2}$$

Fig.4 (vii)



$$i=2p^2 1s^4 P_{1/2} - 1s^2 2p^2 P_{1/2}$$

Excitation rate coefficients (cm^3/s): $R = 10^{-8} R^c e^{-\beta \Delta \epsilon / Z^s}$

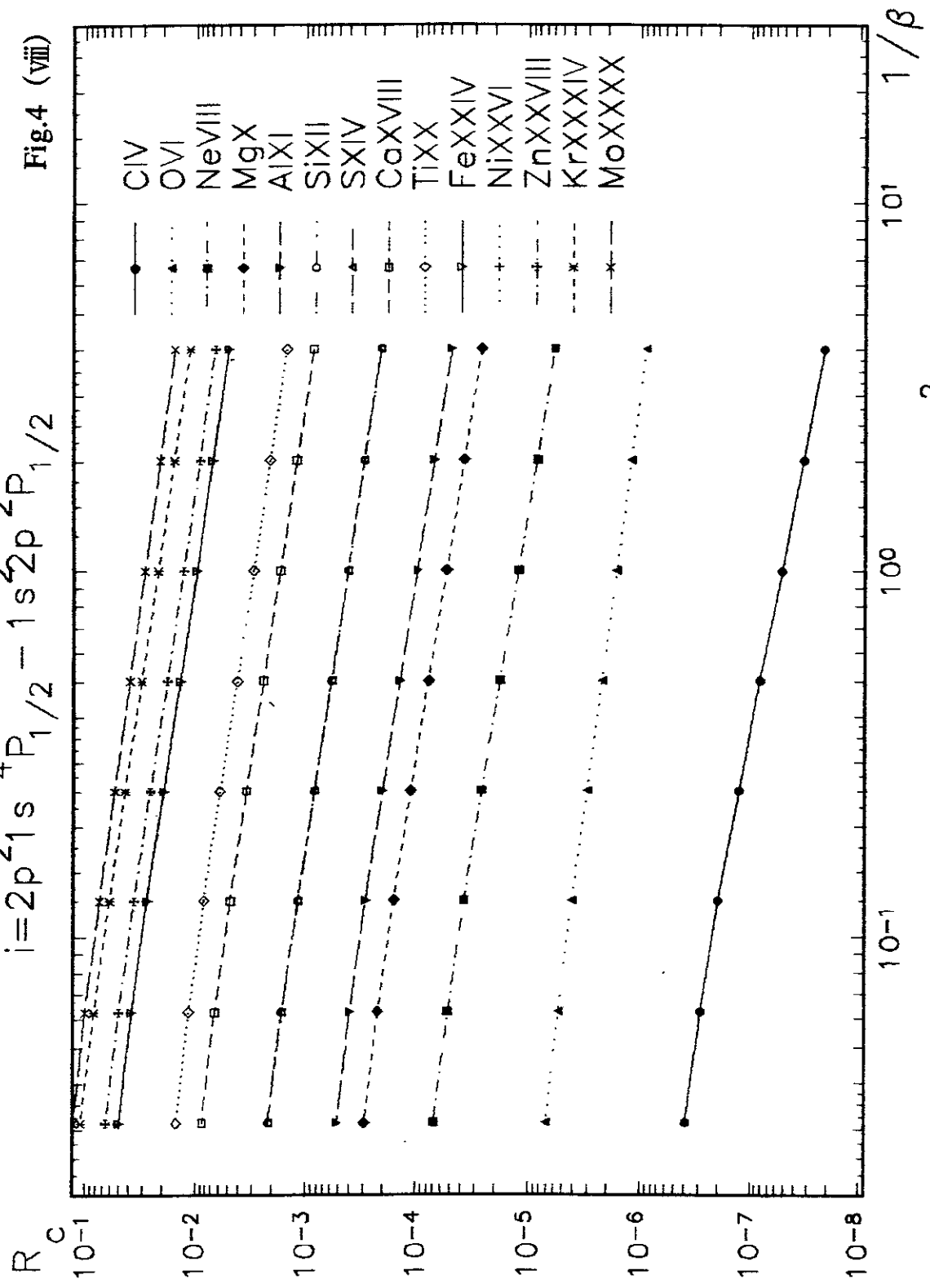


Fig.4 (viii)

Temperature (eV): $T = 13.6 Z_s^2 / \beta$

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