ISSN 0915-6364

NATIONAL INSTITUTE FOR FUSION SCIENCE

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(Received - Aug. 15, 1995)

NIFS-DATA-29 Sep. 1995

RESEARCH REPORT
NIFS-DATA Series

NAGOYA, JAPAN

Cross Sections and Rate Coefficients for Excitation of Δn=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 $1s^22s$ - $1s2s2p$, $1s^22s$ - $1s2s^2$ and $1s^22s$ - $1s2p^2$ transitions of the Li-like ions (CIV, NV, OVI, NeVIII, MgX, AlXI, SiXII, SXIV, ArXVI, CaXVIII, TiXX, FeXXIV, NiXXVI, ZnXXVIII, GeXXX, SeXXXII, KrXXXIIV and MoXXXX) 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 were 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 Kα 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 $1s^22s$ and $1s^22p$ configuration for all fine-structure levels of the 1s2l2l' [23] and 1s2l3l' [24] configurations in Li-like ions with Z=8÷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 $1s^22s$ and $1s^22p$ configurations to all fine-structure levels of 1s2l2l' configurations in Li-like ions with Z= 6÷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 $1s^22s$ configuration to all fine-structure levels 1s2l2l' in Li-like ions with Z= 6÷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 $1s^22s$ configuration to levels $1s^22p$ with the total momentum J=1/2. These data were obtained as a direct excitation of $1s^22s$ to $2s^21s$ level and mixing of $2s^21s$ +$2p^21s$ ones by configuration interaction and influence of the relativistic effects. Branching ratios for the transitions from these excited states to $1s^22p\ ^2P_{1/2}$, $1s^22p\ ^2P_{3/2}$, $1s^22s\ ^2S_{1/2}$ 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]

$$\sigma(QLSJ-Q'L'S'J') = \sum_{\ell}\sigma'_{\ell}(n_1j_1,n'_1j'_1)A'_{\ell} + \sum_{\ell}\sigma''_{\ell}(n_1j_1,n'_1j'_1,)A''_{\ell} \qquad (1)$$

where $\sigma'_{\ell}(n_1j_1,n'_1j'_1)$ is the one-electron cross sections with including the direct and interference parts defined as

$$\sigma'_{\ell}(n_1j_1,n'_1j'_1) = A_0\sum_{\ell_q\ell_k}P_{\ell}(q\ell_q n_1j_1;n'_1j'_1k\ell_k)$$

$$\left(\frac{2}{2\ell+1}P_{\ell}(q\ell_q n_1j_1;n'_1j'_1k\ell_k) - \sum_{\ell'}(-1)^{\ell+\ell'}P_{\ell}(q\ell_q n_1j_1;k\ell_k n'_1j'_1)\begin{Bmatrix} j'_1 & j_1 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix}\right) \qquad (2)$$

and $\sigma''_{\ell}(n_1j_1,n'_1j'_1)$ represents the exchange part:

$$\sigma''_{\ell}(n_1j_1,n'_1j'_1) = 2A_0(2\ell+1)\sum_{\ell_q\ell_k}\left[\sum_{\ell'}(-1)^{\ell+\ell'}P_{\ell}(q\ell_q n_1j_1;k\ell_k n'_1j'_1)\begin{Bmatrix} j'_1 & j_1 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix}\right]^2 \qquad (3)$$

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:

$$P_{\ell}(q\ell_q n_1j_1;n'_1j'_1k\ell_k) = \sqrt{(2\ell_q+1)(2j_1+1)(2\ell_k+1)(2j'_1+1)}\begin{pmatrix} \ell & \ell_q & \ell_k \\ 0 & 0 & 0 \end{pmatrix}$$

$$\times\begin{pmatrix} \ell & j_1 & j'_1 \\ 0 & 0 & 0 \end{pmatrix}\int_0^{\infty}dr_1\int_0^{\infty}dr_2\left[\frac{r_<^{\ell}}{r_>^{\ell+1}} - \frac{\delta(\ell,0)}{r_1}\right]F_{q\ell_q}(r_1)P_{n_1j_1}(r_2)F_{k\ell_k}(r_1)P_{n'_1j'_1}(r_2) \qquad (4)$$

$$P_\ell(q\ell_q n_1 j_1; k\ell_k n_1' j_1') = \sqrt{(2\ell_q+1)(2j_1+1)(2\ell_k+1)(2j_1'+1)}\begin{pmatrix}\ell & \ell_q & j_1'\\ 0 & 0 & 0\end{pmatrix}$$
$$\times\begin{pmatrix}\ell & j_1 & \ell_k\\ 0 & 0 & 0\end{pmatrix}\int_0^\infty dr_1\int_0^\infty dr_2\left[\frac{r_<^\ell}{r_>^{\ell+1}}\right]F_{q\ell_q}(r_1)P_{n_1j_1}(r_2)F_{k\ell_k}(r_2)P_{n_1'j_1'}(r_1) \qquad (5)$$

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 $F_{\varepsilon j}(r)$ 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]:

$$G_{\varepsilon j} = F_{\varepsilon j} - \langle F_{\varepsilon j}|P_{n'j}\rangle P_{n'j}, \qquad G_{\varepsilon' j'} = F_{\varepsilon' j'} - \langle F_{\varepsilon' j'}|P_{nj'}\rangle P_{nj'} \qquad (6)$$

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 :

$$E(QLSJ, Q'L'S'J) = \delta(L,L')\delta(S,S')\left[\delta(Q,Q')\,E_0^N Z^2 + E_1^N Z + E_2^N + E_3^N/Z^3\right.$$

$$\left. + \frac{\alpha^2}{4}\left(Z-\sigma^R\right)^3\left(\delta(Q,Q')\,E_0^R Z + R'\right)\right]$$

$$+ \frac{\alpha^2}{4}\left(Z-\sigma^S\right)^3\left(\delta(Q,Q')\,E_{S0}^{(0)} Z B_1 + E'_{S0} B_1 + E_{SA}^{(0)} B_1 + E_{SS}^{(0)} B_2\right) \tag{7}$$

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 $\left(E_{SO}^{(0)}, \sigma^S, E'_{SO}\right)$, spin-another-orbit $\left(E_{SA}^{(0)}\right)$ and spin-spin $\left(E_{SS}^{(0)}\right)$ interactions.

After the diagonalization of the energy matrix, we obtain the energy eigenvalues ($E(Q_J L_J S_J J)$) and eigenvectors ($C^J(QLS, Q_J L_J S_J)$) 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÷42. The energy data of autoionizing states given in this table are counted from the ground state $1s^2 2s\ ^2S_{1/2}$. 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(^{1}P)1s, K=2s2p(^{3}P)1s, E=2s^2(^{1}S)1s, M=2p^2(^{3}P)1s, F=2p^2(^{1}S)1s,

F=2p^2(^{1}D)1s, S=1s^{2}2s, P=1s^{2}2p (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^{2}2s -1s2s2p excitation is described by 1s and 2p one-electron energies. These energies are obtained as the difference of 1s^{2}2s -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^{2}2s $^2S_{1/2}$) - E(1s2s $^3S_1$). Table 1d lists 2p energies (E(2s2p [^{1,3}P]1s $^{2,4}P_J$) - E(1s2s $^3S_1$) and 2s energies ((E(2s^{2}1s $^2S_{1/2}$) - E(1s2s $^3S_1$). These energy level data were used in the ATOM code for calculation of $P_{nj}(r)$ 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: $j_1^0 j_1^0[L_{12}S_{12}]j_2^0 LSJ - j_3^0 j_2^0[L'_{12}S'_{12}]j_1^0 L'S'J'$ and $j_1^0 j_1^0[L_{12}S_{12}]j_2^0 LSJ - j_2^0 j_2^0[L'_{12}S'_{12}]j_1^0 L'S'J'$ which can be joined into one $j_1 j_1[L_{12}S_{12}]j_2$ LS - $j_3 j_2[L'_{12}S'_{12}]j_1 L'S'J'$. The cross sections for this excitation transitions can be represented as (see eq.(B.1)):

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

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

$$A'_{\ell}(j_1 j_1[L_{12}S_{12}]j_2 L_J S_J J, j_3 j_2[L'_{12}S'_{12}]j_1 L'_J S'_J J') = \frac{1}{(2J+1)}$$

$$\times\Bigg[\sum_{QLSQ'L'S'}\sum C^J(QLS,Q_J L_J S_J)C^{J'}(Q'L'S',Q'_J L'_J S'_J)$$

$$\times\frac{1}{2}\sum_{L''_{12}S''_{12}}\sum_{\ell_1\ell_2} C_{\ell_1 j_1 \ell_2 j_1 \ell_3 j_2}(L_{12}S_{12},L''_{12}S''_{12};LS) \qquad (11)$$

$$\times C_{\ell_1 j_3 \ell_2 j_2 \ell'_3 j_1}(L'_{12}S'_{12},L''_{12}S''_{12};L'S')f_{\ell}(\ell_3\ell'_3;LSJ,L'S'J';L''_{12})\Bigg]^2$$

$$A''_{\ell}(j_1 j_1[L_{12}S_{12}]j_2 L_J S_J J, j_3 j_2[L'_{12}S'_{12}]j_1 L'_J S'_J J') = \frac{1}{2(2J+1)(2\ell+1)}$$

$$\sum_{a_1}\sum_{a_2}\Bigg[\sum_{QLSQ'L'S'}\sum C^J(QLS,Q_J L_J S_J)C^{J'}(Q'L'S',Q'_J L'_J S'_J)$$

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

$$\times C_{\ell_1 j_3 \ell_2 j_2 \ell'_3 j_1}(L'_{12}S'_{12},L''_{12}S''_{12};L'S')f_{\ell}^{a_1 a_2}(\ell_3\ell'_3;LSJ,L'S'J';L''_{12}S''_{12})\Bigg]^2 \qquad (12)$$

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

$$N'_{\ell}(j_1 j_1[L_{12}S_{12}]j_2 LSJ, j_3 j_2[L'_{12}S'_{12}]j_1 L'SJ') = \frac{1}{(2J+1)}$$

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

$$\times f_{\ell}(\ell_3\ell'_3;LSJ,L'S'J';L''_{12})\Bigg]^2 \qquad (13)$$

$$N''_{\ell}(j_1 j_1[L_{12}S_{12}]j_2 LSJ, j_3 j_2[L'_{12}S'_{12}]j_1 L'S'J') = \frac{1}{2(2J+1)(2\ell+1)}$$

$$\sum_{a_1}\sum_{a_2}\left[\frac{1}{2}\sum_{L''_{12}S''_{12}}\sum_{\ell_1\ell_2} C_{\ell_1 j_1 \ell_2 j_1 \ell_3 j_2}(L_{12}S_{12}, L''_{12}S''_{12}; LS)\right.$$

$$\left.\times C_{\ell_1 j_3 \ell_2 j_2 \ell'_3 j_1}(L'_{12}S'_{12}, L''_{12}S''_{12}; L'S') f_{\ell}^{a_1 a_2}(\ell_3 \ell'_3; LSJ, L'S'J'; L''_{12}S''_{12})\right]^2 \qquad (14)$$

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

$$N_{\ell}(1s^2[^1S]j_2\ LSJ, j_3 j_2[L'_{12}S'_{12}]ls\ L'S'J') =$$

$$\frac{(2S'_{12}+1)(2L'+1)(2J'+1)}{2(2j_3+1)}\begin{Bmatrix} J & J' & j_3 \\ L' & L & S \end{Bmatrix}^2 \delta(j_2, L)\delta(j_3, \ell)\delta(L'_{12}, L')\delta(S, S') \qquad (15)$$

$$N''_{\ell}(1s^2[^1S]j_2\ LSJ, j_3 j_2[L'_{12}S'_{12}]ls\ L'S'J') = \delta(j_2, L)\delta(j_3, \ell)\delta(L'_{12}, L')$$

$$\times((2S'_{12}+1)(2L'+1)(2S+1)(2S'+1)(2J'+1)/2(2\ell+1))\sum_{a_1}\sum_{a_2}(2a_1+1)(2a_2+1)$$

$$\times\begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix}^2 \begin{Bmatrix} J & j_3 & a_1 \\ L' & S & L \end{Bmatrix}^2 \begin{Bmatrix} a_1 & J' & a_2 \\ S' & S & L' \end{Bmatrix}^2 \qquad (16)$$

Let us consider $1s^2[^1S]2s\ ^2S_{1/2}$ - $2p2s[^{1,3}P]1s\ ^{2,4}P_J$ excitation. For this special case we obtain from eqs.(15) and (16):

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

$$N''_{\ell}(1s^2[^1S]2s\ ^2S_{1/2}, 2p2s[1S'_{12}]ls\ 1S'J') = \delta(\ell, 1)\frac{(2S'_{12}+1)(2S'+1)(2J'+1)}{4(2\ell+1)}$$

$$\times\sum_{a_1}\sum_{a_2}(2a_1+1)(2a_2+1)\begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix}^2 \begin{Bmatrix} a_1 & J' & a_2 \\ S' & 1/2 & 1 \end{Bmatrix}^2 \qquad (18)$$

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

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

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:

$$N_\ell(1s^2[^1S]j_2\ LSJ, j_2 j_2[L'_{12}S'_{12}]1s\,L'S'J') = \frac{(2S'_{12}+1)(2L'+1)(2J'+1)}{(2j_2+1)}\begin{Bmatrix} J & J' & j_2 \\ L' & L & S \end{Bmatrix}^2 \delta(j_2,L)\delta(j_2,\ell)\delta(L'_{12},L')\delta(S,S') \tag{20}$$

$$N''_\ell(1s^2[^1S]j_2\ LSJ, j_2 j_2[L'_{12}S'_{12}]1s\,L'S'J') = \delta(j_2,L)\delta(j_2,\ell)\delta(L'_{12},L') \times((2S'_{12}+1)(2L'+1)(2S+1)(2S'+1)(2J'+1)/(2\ell+1))\sum_{a_1}\sum_{a_2}(2a_1+1)(2a_2+1) \times\begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix}^2\begin{Bmatrix} J & j_2 & a_1 \\ L' & S & L \end{Bmatrix}^2\begin{Bmatrix} a_1 & J' & a_2 \\ S' & S & L' \end{Bmatrix}^2 \tag{21}$$

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

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

$$N''_\ell(1s^2[^1S]2s\ ^2S_{1/2}, 2s^2[^1S]1s\ ^2S_{1/2}) = \delta(\ell,0)\frac{1}{4}\sum_{a_1}\sum_{a_2=0,1}(2a_2+1)\delta(a_1,\frac{1}{2}) = \delta(\ell,0) \tag{23}$$

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

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

$$N''_\ell(1s^2[^1S]2p\ ^2P_J, 2p^2[L'_{12}S'_{12}]1s\,L'S'J') = \delta(\ell,1)\delta(L'_{12},L') \times\frac{1}{3}(2S'_{12}+1)(2L'+1)(2S'+1)(2J'+1)\sum_{a_1}\sum_{a_2}(2a_1+1)(2a_2+1) \times\begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix}^2\begin{Bmatrix} J & 1 & a_1 \\ L' & 1/2 & 1 \end{Bmatrix}^2\begin{Bmatrix} a_1 & J' & a_2 \\ S' & 1/2 & L' \end{Bmatrix}^2 \tag{25}$$

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 $C^J(QLS,Q_JL_JS_J)$ (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 $1s^2[^1S]2s\ ^2S_{1/2}$ - $2p2s[^{1,3}P]1s\ ^{2,4}P_J$ transitions since N" is independent of all quantum numbers except J'. In this case

$$\left[\sum_{QLS} C^J(QLS,Q_JL_JS_J)\right]^2 = 1 \qquad (26)$$

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 $(C^J(QLS,Q_JL_JS_J))^2$ factor in eqs.(10) and (11) where J=1/2, QLS=$2s^2[^1S]1s\ ^2S_{1/2}$ and $Q_JL_JS_J$ = $2s^2[^1S]1s\ ^2S_{1/2}$,$2p^2[^1S]1s\ ^2S_{1/2}$, $2p^2[^1S]1s\ ^2P_{1/2}$, $2p^2[^1S]1s\ ^4P_{1/2}$. 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:

$$1s^2 2s\ {}^2S_{1/2} + e = (1s2s^2\,{}^2S_{1/2} + 1s2p^2\,{}^2S_{1/2} + 1s2p^2\,{}^2P_{1/2} + 1s2p^2\,{}^4P_{1/2}) + e$$
$$\downarrow \qquad \downarrow \qquad \downarrow \qquad \downarrow$$
$$1s^2 2p\ {}^2P_J + \hbar\nu \quad \text{with } J = 1/2, 3/2 \tag{27}$$

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:($1s2s^2\,{}^2S_{1/2}$ - $1s^22p\,{}^2P_J$, $1s2p^2\,{}^2S_{1/2}$ - $1s^22p\,{}^2P_J$, $1s2p^2\,{}^2P_{1/2}$ - $1s^22p\,{}^2P_J$, $1s2p^2\,{}^4P_{1/2}$ - $1s^22p\,{}^2P_J$ with J=1/2 and 3/2). It should be noted that only two lines ($1s2p^2\,{}^2S_{1/2}$ - $1s^22p\,{}^2P_J$, $1s2p^2\,{}^2P_{1/2}$ - $1s^22p\,{}^2P_J$) are allowed in LS coupling scheme, the $1s2s^2\,{}^2S_{1/2}$ - $1s^22p\,{}^2P_J$ line is allowed by superposition of configurations ($1s2s^2$ + $1s2p^2$) and data for the $1s2p^2\,{}^4P_{1/2}$ - $1s^22p\,{}^2P_J$ 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):

$$K(Q'L'S'J'-QLSJ) = \frac{Ar(Q'L'S'J'-QLSJ)}{Ar(Q'L'S'J') + \Gamma(Q'L'S'J')},$$
$$Ar(Q'L'S'J') = \sum_{QLSJ} Ar(Q'L'S'J'-QLSJ) \tag{28}$$

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 $2s2p(^{1,3}P)1s\ {}^{2,4}P_J$ - $1s^22s\ {}^2S_{1/2}$ 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.

$$\sigma=\sigma_C x\frac{a_0^2}{Z_S^4}\ (cm^2),\ E=13.6Z_S^2(\Delta\varepsilon+u)\ (eV) \qquad (29)$$

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):

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

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 vise 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'σ') for the first case and the exchanging part (A"σ") 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 ÷ 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÷1.28.

Table 5 represents cross sections of 1s-2s excitation (σ_C) for 8 emission lines $1s^22p$ -$1s2s^2$, $1s^22p$ -$1s2p^2$ for the 17 Li-like ions. The Gabriel's designations [1] were used for these lines also:

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=$2p^21s\ ^4P_{1/2}$ - $1s^22p\ ^2P_{1/2}$ (31)

The values of these cross sections are much less than for 6 above mentioned transitions since there is only one level ($2s^21s\ ^2S_{1/2}$) which can be directly excited from the ground $1s^22s\ ^2S_{1/2}$ 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 ($2p^21s\ ^2S_{1/2}$ and $2p^21s\ ^2P_{1/2}$) which are in the same complex as $2s^21s$ $^2S_{1/2}$ level but those two levels can not be excited directly but only by superposition of

$2s^2 1s + 2p^2 1s$ 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 $n=2\div6$ 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 $1s^2 2p - 1s2s^2$, $1s^2 2p - 1s2p^2$ 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 $Z_S^2(\mathrm{Ry})$ for the same 17 Li-like ions. R is obtained from the plotted R_C values by using the next formula:

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

where $\Delta\varepsilon$ is the transition energy in units of $Z_S^2(\mathrm{Ry})$ 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 ant 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 $2s2p(^{1,3}P)1s\ ^{2,4}P_J$ - $1s^2 2s\ ^2S_{1/2}$ 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 are 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.

Acknowledgments

The research described in this publication was made possible in part (U.I.Safronova) by Grant N NL3000 from the International Science Foundation and Russian Grant for Fundamental Research (95-02-04534a).

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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]

$$\delta(n_0\ell_0,n_1\ell_1)=\frac{16\pi a_0^2}{q^2}\frac{1}{(2\ell_0+1)}\sum_{\chi}\frac{1}{2\chi+1}\Big|P_\chi(q\ell_q n_0\ell_0;n_1\ell_1 k\ell_k)$$
$$-\frac{1}{2}\sum_{\chi'}(2\chi+1)(-1)^{\chi+\chi'}\begin{Bmatrix}\ell_1 & \ell_0 & \chi\\ \ell_k & \ell_q & \chi'\end{Bmatrix}P_{\chi'}(q\ell_q n_0\ell;k\ell_k n_1\ell_1)\Big|^2 \tag{A.1}$$

where

$$P_\chi(q\ell_q n_0\ell_0;n_1\ell_1 k\ell_k)=\sqrt{(2\ell_q+1)(2\ell_0+1)(2\ell_k+1)(2\ell_1+1)}\begin{pmatrix}\chi & \ell_q & \ell_k\\ 0 & 0 & 0\end{pmatrix}$$
$$\times\begin{pmatrix}\chi & \ell_0 & \ell_1\\ 0 & 0 & 0\end{pmatrix}\int_0^\infty dr_1\int_0^\infty dr_2\left[\frac{r_<^\chi}{r_>^{\chi+1}}-\frac{\delta(\chi,0)}{r_1}\right]F_{q\ell_q}(r_1)P_{n_0\ell_0}(r_2)F_{k\ell_k}(r_1)P_{n_1\ell_1}(r_2) \tag{A.2}$$

$$P_\chi(q\ell_q n_0\ell_0;k\ell_k n_1\ell_1)=\sqrt{(2\ell_q+1)(2\ell_0+1)(2\ell_k+1)(2\ell_1+1)}\begin{pmatrix}\chi & \ell_q & \ell_1\\ 0 & 0 & 0\end{pmatrix}$$
$$\times\begin{pmatrix}\chi & \ell_0 & \ell_k\\ 0 & 0 & 0\end{pmatrix}\int_0^\infty dr_1\int_0^\infty dr_2\left[\frac{r_<^\chi}{r_>^{\chi+1}}\right]F_{q\ell_q}(r_1)P_{n_0\ell_0}(r_2)F_{k\ell_k}(r_2)P_{n_1\ell_1}(r_1) \tag{A.3}$$

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

$$P(QLSMM_S,Q'L'S'M'M_S')=\frac{1}{(n-1)!}\sum_{\alpha_1\cdots\alpha_n}\sum_{\alpha_{n'}}C^{QLS}_{\alpha_1\cdots\alpha_n}C^{Q'L'S'}_{\alpha\cdots\alpha_{n-1}\alpha_{n'}}\left[V_{q\alpha_n;\alpha_n k}-V_{q\alpha_n;k\alpha_{n'}}\right] \tag{A.4}$$

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: $Q=j_1j_2[L_{12}S_{12}]j_3[L_{13}S_{13}]j_4[L_{14}S_{14}]\ldots[L_{1n-1}S_{1n-1}]j_n$). 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

$$\sum_{\alpha_1\cdots\alpha_n} C^{*Q}_{\alpha_1\cdots\alpha_n} C^{Q'}_{\alpha_1\cdots\alpha_n} = n!\delta(Q,Q') \qquad (A.5)$$

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

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

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

where P_l is defined by eqs.(A.2) and (A.3) accordingly. In the results of calculations we can obtain for $P(QLSMM_S,Q'L'S'M'M'_S)$:

$$P(QLSMM_S,Q'L'S'M'M'_S) = \frac{1}{(n-1)!}\sum_{L''_{12}S''_{12}\cdots L''_{1n-1}S''_{1n-1}}\sum_{\ell_q m_q \ell_k m_k}\sum_{\ell_1\cdots\ell_n\ell'_n}\sum_{a\mu}\sum_{\ell}(-1)^{M'+m_q}$$
$$\times Y(\ell_q m_q\theta_q\varphi_q,\ell_k m_k\theta_k\varphi_k)\begin{pmatrix}\ell_q & \ell_k & a\\ -m_q & m_k & \mu\end{pmatrix}\begin{pmatrix}L & L' & a\\ M & -M' & \mu\end{pmatrix}\sqrt{(2L+1)(2L'+1)}$$
$$\times C_{\ell_1 j_1\cdots\ell_n j_n}(L_{12}S_{12},L''_{12}S''_{12}\cdots LS) C_{\ell_1 j'_1\ell_2 j'_2\cdots\ell_{n-1}j'_{n-1}\ell'_n j'_n}(L'_{12}S'_{12}L''_{12}S''_{12}\cdots L'S')$$

$$\times[\delta(a,\ell)\delta(m_{s_k},m_{s_q})\delta(M_S,M'_S)\delta(S,S')P_\ell(q\ell_q n_n\ell_n;n'_n\ell'_n k\ell_k)(-1)^{L_{n-1}}\begin{Bmatrix}L & L' & \ell\\ \ell'_n & \ell_n & L_{n-1}\end{Bmatrix}$$
$$-P_\ell(q\ell_q n_n\ell_n;k\ell_k n'_n\ell'_n)(2a+1)\begin{Bmatrix}\ell'_n & \ell_n & a\\ \ell_k & \ell_q & \ell\end{Bmatrix}\begin{Bmatrix}L & L' & a\\ \ell'_n & \ell_n & L_{n-1}\end{Bmatrix}\sqrt{(2S+1)(2S'+1)}$$
$$\times(-1)^{a+\ell+L_{n-1}}\sum_{M_{S_{n-1}}}(-1)^{2S_{n-1}-1+M_S+M'_S}\begin{pmatrix}S_{n-1} & 1/2 & S\\ M_{S_{n-1}} & m_{s_q} & -M_S\end{pmatrix}\begin{pmatrix}S_{n-1} & 1/2 & S'\\ M_{S_{n-1}} & m_{s_q} & -M_{S'}\end{pmatrix}] \qquad (A.8)$$

where we use designations

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

The amplitude of excitation in intermediate coupling scheme should be determine by $P(QLSMM_S, Q'L'S'M'M'_S)$ and intermediate mixing coefficients $C^J(Q_J L_J S_J, QLS)$

$$P(Q_J J M_J, Q'_J J' M'_J) = \sum_{QLSQ'L'S'} \sum_{MM'M_S M'_S} C^J(Q_J L_J S_J, QLS) C^{J'}(Q'L'S', Q'_J L'_J S'_J)$$
$$\times (-1)^{L-S+M_J} \sqrt{(2J+!)} \begin{pmatrix} L & S & J \\ M & M_S & -M_J \end{pmatrix} (-1)^{L'-S'+M'_J} \sqrt{(2J'+1)} \begin{pmatrix} L' & S' & J' \\ M' & M'_S & -M'_J \end{pmatrix}$$
$$\times P(QLSMM_S, Q'L'S'M'M'_S) \qquad (A.10)$$

The intermediate mixing coefficients $C^J(Q_J L_J S_J, QLS)$ 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;

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

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

$$\sigma(j_1 j_2[L_{12}S_{12}]j_3 \cdots L_J S_J J, j_1' j_2'[L_{12}']j_3' \cdots L_J' S_J' J') =$$
$$= \frac{A_0}{(2J+1)} \sum_{m_{S_q} m_{S_k}} \sum_{M_J M_J'} \int d\omega_k d\omega_q \left| P(Q_J J M_J, Q_j' J' M_J') \right|^2 \qquad (A.12)$$

where $A_0=8\pi(a_0)^2/q^2(2j_n+1)$. 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).

$$A_1 = \int d\omega_k d\omega_q Y(\ell_q m_q \theta_q \varphi_q, \ell_k m_k \theta_k \varphi_k) Y^*(\ell'_q m'_q \theta_q \varphi_q, \ell'_k m'_k \theta_k \varphi_k)$$
$$= \delta(\ell_q, \ell'_q)\delta(m_q, m'_q)\delta(\ell_k, \ell'_k)\delta(m_k, m'_k) \qquad (A.13)$$

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

$$A_2 = \sum_{\ell_1 m_1 \ell_3 m_3} \sum_{a\mu a_1\mu_1 a_2\mu_2} \sum_{a'\mu' a_1'\mu_1' a_2'\mu_2'} \begin{pmatrix} \ell_1 & \ell_3 & a \\ -m_1 & m_3 & \mu \end{pmatrix} \begin{pmatrix} \ell_1 & \ell_3 & a \\ -m_1 & m_3 & \mu' \end{pmatrix}$$

$$\times \sum_{M_J M_J'} \sum_{M_{S_q} M_{S_k}} \begin{pmatrix} J & a & a_1 \\ -M_J & -\mu & -\mu_1 \end{pmatrix} \begin{pmatrix} a_1 & J' & a_2 \\ \mu_1 & M_J & \mu_2 \end{pmatrix} \begin{pmatrix} a_2 & 1/2 & 1/2 \\ -\mu_2 & m_{S_q} & m_{S_k} \end{pmatrix}$$
$$\times \begin{pmatrix} J & a' & a_1' \\ -M_J & -\mu' & -\mu_1' \end{pmatrix} \begin{pmatrix} a_1' & J' & a_2' \\ \mu_1' & M'_J & \mu_2' \end{pmatrix} \begin{pmatrix} a_2' & 1/2 & 1/2 \\ -\mu_2' & m_{S_q} & m_{S_k} \end{pmatrix} =$$

$$= \sum_{a\mu a_1\mu_1 a_2\mu_2} \sum_{a'\mu' a_1'\mu_1' a_2'\mu_2'} \sum_{M_J M_J'} \delta(a,a')\delta(\mu,\mu') \frac{1}{(2a+1)} \frac{1}{(2a_2+1)} \delta(a_2, a_2')\delta(\mu_2, \mu_2')$$

$$\times \begin{pmatrix} J & a & a_1 \\ -M_J & -\mu & -\mu_1 \end{pmatrix} \begin{pmatrix} J & a & a_1' \\ -M_J & -\mu & -\mu_1' \end{pmatrix} \begin{pmatrix} a_1 & J' & a_2 \\ \mu_1 & M_J' & \mu_2 \end{pmatrix} \begin{pmatrix} a_1' & J' & a_2' \\ \mu_1' & M_J' & \mu_2' \end{pmatrix} =$$

$$= \sum_{aa_1a_2} \sum_{\mu_1} \frac{1}{(2a+1)} \frac{1}{(2a_2+1)} \frac{1}{(2a_1+1)^2} = \sum_{aa_1a_2} \frac{1}{(2a+1)} \frac{1}{(2a_1+1)} \frac{1}{(2a_2+1)} \qquad (A.14)$$

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

$$\sigma(j_1 j_2[L_{12}S_{12}]j_3 \cdots L_J S_J J, j_1' j_2'[L_{12}']j_3' \cdots L_J' S_J' J') = \frac{A_0}{(2J+1)}(R_1 + R_2 + R_3) \tag{A.15}$$

where

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

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

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

$$R_3 = \sum_{\ell_q \ell_k} \sum_{\ell\ell'} \sum_{\ell_n \ell_n' \ell_n'' \ell_n'''} 2P_\ell(q\ell_q n_n \ell_n; n_n' \ell_n' k\ell_k) P_{\ell'}(q\ell_q n_n \ell_n; k\ell_k n_n' \ell_n') \begin{Bmatrix} \ell_n'' & \ell_n' & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix}$$

$$(-1)^{\ell+\ell'+1} S_\ell(n_n \ell_n, n_n' \ell_n') S_\ell(n_n'' \ell_n'', n_n''' \ell_n''') \tag{A.18}$$

where the next designations were used:

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

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

(A.20)

$$M_a^{a_1a_2}(n_n\ell_n,n_n'\ell_n')=\frac{1}{(n-1)!}\sum_{QLSQ'L'S'}\sum C^J(QLS,Q_JL_JS_J)C^{J'}(Q'L'S',Q_J'L_J'S_J')$$

$$\times\sum_{L_{12}''S_{12}''\cdots L_{1n-1}''S_{1n-1}''}\sum_{\ell_1\cdots\ell_{n-1}}C_{\ell_1j_1\cdots\ell_nj_n}(L_{12}S_{12}L_{12}''S_{12}'',\cdots L_{1n-1}S_{1n-1}L_{1n-1}''S_{1n-1}'',LS)$$

$$\times C_{\ell_1j_1\cdots\ell_{n-1}j_{n-1}'\ell_n'j_n}(L'_{12}\,S'_{12}\,L_{12}''S_{12}'',\cdots L'_{1n-1}\,S'_{1n-1}\,L_{1n-1}''S_{1n-1}'',L'S')$$

$$\times f_a^{a_1a_2}(\ell_n\ell_n';LSJ,L'S'J';L_{1n-1}''S_{1n-1}'')$$

(A.21)

$$f_a^{a_1a_2}(\ell_n\ell_n';LSJ,L'S'J';L_{1n-1}''S_{1n-1}'')=$$

$$(-1)^{a+L_{1n-1}''+S_{1n-1}''}\sqrt{(2a+1)(2L+1)(2L'+1)}\begin{Bmatrix}L & L' & a\\ \ell_n' & \ell_n & L_{1n-1}''\end{Bmatrix}\begin{Bmatrix}a_2 & 1/2 & 1/2\\ S_{1n-1}'' & S & S'\end{Bmatrix}$$

$$\times(-1)^{2a_1-J+J'+a+L'+S'+1/2'}\sqrt{(2a_1+1)(2a_2+1)(2J+1)(2J'+1)(2S+1)(2S'+1)}$$

$$\times\begin{Bmatrix}J & a & a_1\\ L' & S & L\end{Bmatrix}\begin{Bmatrix}a_1 & J' & a_2\\ S' & S & L'\end{Bmatrix}$$

(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 coeefficient). In this case we can remove one sum in (A.17)

$$\Re=\sum_{a_1a_2}M_a^{a_1a_2}(n_n\ell_n,n_n'\ell_n')M_a^{a_1a_2}(n_n''\ell_n'',n_n'''\ell_n''')=\Re^0+\Re^1$$

$$\Re^0=\sum_{a_1}M_a^{a_10}(n_n\ell_n,n_n'\ell_n')M_a^{a_10}(n_n''\ell_n'',n_n'''\ell_n'''),\qquad(A.23)$$

$$\Re^1=\sum_{a_1}M_a^{a_11}(n_n\ell_n,n_n'\ell_n')M_a^{a_11}(n_n''\ell_n'',n_n'''\ell_n''')$$

After simple but cumbersome calculations we found

$$M_a^{a_10}(n_n\ell_n,n_n'\ell_n')=S_a(n_n\ell_n,n_n'\ell_n')\delta(a_1,J')\sqrt{(2a+1)/2}\qquad(A.24)$$

and

$$\Re^0 = \frac{2a+1}{2} S_a(n_n\ell_n, n'_n\ell'_n) S_a(n''_n\ell''_n, n'''_n\ell'''_n) \tag{A.25}$$

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

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

where

$$M_\ell^{a_1}(n_n\ell_n, n'_n\ell'_n) = \frac{1}{(n-1)!} \sum_{QLSQ'L'S'} \sum C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J, S'_J)$$

$$\times \sum_{L''_{12} S''_{12} \ldots L''_{1n-1} S''_{1n-1}} \sum C_{\ell_1 j_1 \ldots \ell_n j_n} (L_{12} S_{12} L''_{12} S''_{12}, \cdots L_{1n-1} S_{1n-1} L''_{1n-1} S''_{1n-1}, LS)$$
$$\times C_{\ell_1 j_1 \ldots \ell_{n-1} j_{n-1} \ell'_n j'_n} (L'_{12} S'_{12} L''_{12} S''_{12}, \cdots L'_{1n-1} S'_{1n-1} L''_{1n-1} S''_{1n-1}, L'S')$$
$$f_\ell^{a_2}(\ell_n \ell'_n; LSJ, L'S'J'; L''_{1n-1} S''_{1n-1}) \tag{A.27}$$

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

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

$$\sigma(j_1 j_2 L_J S_J J, j_1' j_2' L_J' S_J' J') = \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \Bigg| \sum_{n_2 \ell_2 n_2' \ell_2'} \sum_{QLS} \sum_{Q'L'S'} C^J(QLS, Q_J L_J S_J)$$
$$\times C^{J'}(Q'L'S', Q_J' L_J' S_J') \sum_{\ell_1} C_{\ell_1 j_1 \ell_2 j_2}(LS) C_{\ell_1 j_1' \ell_2' j_2'}(L'S') f_\ell(\ell_2 \ell_2'; LSJ, L'S'J'; \ell_1)$$
$$\times \left(\sqrt{\frac{2}{2\ell+1}} P_\ell(q \ell_q n_2 \ell_2; n_2' \ell_2' k \ell_k) - \sqrt{\frac{2\ell+1}{2}} \sum_{\ell'} (-1)^{\ell+\ell'} P_\ell(q \ell_q n_2 \ell_2; k \ell_k n_2' \ell_2') \right.$$
$$\left. \times \begin{Bmatrix} \ell_2' & \ell_2 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \right)^2 \Bigg|$$
$$+ \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \sum_{a_1} \Bigg| \sum_{\ell'} \sum_{n_2 \ell_2 n_2' \ell_2'} \sum_{QLS} \sum_{Q'L'S'} C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q_J' L_J' S_J')$$
$$\times \sum_{\ell_1} C_{\ell_1 j_1 \ell_2 j_2}(LS) C_{\ell_1 j_1 \ell_2' j_2'}(L'S') f_\ell^{a_1}(\ell_2 \ell_2'; LSJ, L'S'J'; \ell_1 \frac{1}{2})$$
$$\times (-1)^{\ell+\ell'} P_{\ell'}(q \ell_q n_2 \ell_2; k \ell_k n_2' \ell_2') \begin{Bmatrix} \ell_2' & \ell_2 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \Bigg|^2$$

(A.29)

where

$$f_\ell(\ell_2 \ell_2'; LSJ, L'S'J'; \ell_1) = (-1)^{\ell_1+\ell-S+J} \delta(S,S') \begin{Bmatrix} L & L' & \ell \\ \ell_2' & \ell_2 & \ell_1 \end{Bmatrix} \begin{Bmatrix} J & J' & \ell \\ L' & L & S \end{Bmatrix}$$
$$\times \sqrt{(2L+1)(2L'+1)(2J+1)(2J'+1)}$$

(A.30)

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

(A.31)

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

$$\Re_\ell(q\ell_q n_2\ell_2; n'_2\ell'_2 k\ell_k) = \sqrt{\frac{2}{2\ell+1}} P_\ell(q\ell_q n_2\ell_2; n'_2\ell'_2 k\ell_k)$$
$$-\sqrt{\frac{2\ell+1}{2}}\sum_{\ell'}(-1)^{\ell+\ell'}\begin{Bmatrix}\ell'_2 & \ell_2 & \ell\\ \ell_k & \ell_q & \ell'\end{Bmatrix} P_{\ell'}(q\ell_q n_2\ell_2; k\ell_k n'_2\ell'_2)$$

(A.32)

$$\Re_\ell(q\ell_q n_2\ell_2; k\ell_k n'_2\ell'_2) = \sum_{\ell'}(-1)^{\ell+\ell'}\begin{Bmatrix}\ell'_2 & \ell_2 & \ell\\ \ell_k & \ell_q & \ell'\end{Bmatrix} P_{\ell'}(q\ell_q n_2\ell_2; k\ell_k n'_2\ell'_2)$$

(A.33)

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

$$\sigma(j_1 j_2 L_J S_J J, j'_1 j'_2 L'_J S'_J J') = \frac{A_0}{(2J+!)}\sum_{\ell_q\ell_k}\sum_{\ell}\Bigg|\sum_{n_2\ell_2 n'_2\ell'_2}\sum_{QLS}\sum_{Q'L'S'} C^J(QLS, Q_J L_J S_J)$$
$$\times C^{J'}(Q'L'S', Q'_J L'_J S'_J)\sum_{\ell_1} C_{\ell_1 j_1 \ell_2 j_2}(LS) C_{\ell_1 j_1 \ell'_2 j'_2}(L'S')$$
$$\times f_\ell(\ell_2\ell'_2; LSJ, L'S'J'; \ell_1)\Re_\ell(q\ell_q n_2\ell_2; n'_2\ell'_2 k\ell_k)\Bigg|^2$$

$$+\frac{A_0}{(2J+!)}\sum_{\ell_q\ell_k}\sum_{\ell}\sum_{a_1}\Bigg|\sum_{n_2\ell_2 n'_2\ell'_2}\sum_{QLS}\sum_{Q'L'S'} C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J)$$
$$\times\sum_{\ell_1} C_{\ell_1 j_1 \ell_2 j_2}(LS) C_{\ell_1 j_1 \ell'_2 j'_2}(L'S')$$
$$\times f_\ell^{a_1}(\ell_2\ell'_2; LSJ, L'S'J'; \ell_1 \frac{1}{2})\Re_\ell(q\ell_q n_2\ell_2; k\ell_k n'_2\ell'_2)\Bigg|^2$$

(A.34)

Sums over $n_2 l_2$, $n'_2 l'_2$ and l_1 can be simple calculated by using the definition for C

$$C_{\ell_1 j_1 \ell_2 j_2}(LS) = N(j_1 j_2)\left(\delta(\ell_1, j_1)\delta(\ell_2, j_2) + (-1)^{L+S+j_1+j_2}\delta(\ell_1, j_2)\delta(\ell_1, j_2)\right)$$

(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 quantun mumbers in order do not encoumber this formula. After simple but cumbersome calculations we obtain

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

$$\sigma(j_1 j_2 L_J S_J J, j'_1 j'_2 L'_J S'_J J') = \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \Bigg[\sum_{QLS\,Q'L'S'} \sum C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J)$$
$$\times N(j_1 j_2) N(j'_1 j'_2) \Big(\delta(j_1, j'_1) f_\ell(j_2 j'_2; LSJ, L'S'J'; j_1) \Re_\ell(q\ell_q n_2 j_2; n'_2 j'_2 k \ell_k)$$
$$+ (-1)^{L'+S'+j'_2+j'_1} \delta(j_1, j'_2) f_\ell(j_2 j'_1; LSJ, L'S'J'; j_1) \Re_\ell(q\ell_q n_2 j_2; n'_2 j'_1 k \ell_k)$$
$$+ (-1)^{L+S+j_2+j_1} \delta(j_2, j'_1) f_\ell(j_1 j'_2; LSJ, L'S'J'; j_2) \Re_\ell(q\ell_q n_2 j_1; n'_2 j'_2 k \ell_k)$$
$$+ (-1)^{L+S+L'+S'+j_2+j_1+j'_2+j'_1} \delta(j_2, j'_2) f_\ell(j_1 j'_1; LSJ, L'S'J'; j_2) \Re_\ell(q\ell_q n_2 j_1; n'_2 j'_1 k \ell_k) \Big) \Bigg]^2$$
$$+ \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \sum_{a_1} \Bigg[\sum_{QLS\,Q'L'S'} \sum C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J)$$
$$\times N(j_1 j_2) N(j'_1 j'_2) \Big(\delta(j_1, j'_1) f^{a_1}_\ell(j_2 j'_2; LSJ, L'S'J'; j_1 \tfrac{1}{2}) \Re_\ell(q\ell_q n_2 j_2; k\ell_k n'_2 j'_2)$$
$$+ (-1)^{L'+S'+j'_2+j'_1} \delta(j_1, j'_2) f^{a_1}_\ell(j_2 j'_1; LSJ, L'S'J'; j_1 \tfrac{1}{2}) \Re_\ell(q\ell_q n_2 j_2; k\ell_k n'_2 j'_1)$$
$$+ (-1)^{L+S+j_2+j_1} \delta(j_2, j'_1) f^{a_1}_\ell(j_1 j'_2; LSJ, L'S'J'; j_2 \tfrac{1}{2}) \Re_\ell(q\ell_q n_2 j_1; k\ell_k n'_2 j'_2)$$
$$+ (-1)^{L+S+L'+S'+j_2+j_1+j'_2+j'_1} \delta(j_2, j'_2) f^{a_1}_\ell(j_1 j'_1; LSJ, L'S'J'; j_2 \tfrac{1}{2}) \Re_\ell(q\ell_q n_2 j_1; k\ell_k n'_2 j'_1) \Big) \Bigg]^2$$

(36)

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

$$\sigma(j_1 j_2 L_J S_J J, j_1 j'_2 L'_J S'_J J') = \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \Bigg[\sum_{QLS\,Q'L'S'} \sum C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J)$$
$$\times N(j_1 j_2) N(j_1 j'_2) f_\ell(j_2 j'_2; LSJ, L'S'J'; j_1) \Re_\ell(q\ell_q n_2 j_2; n'_2 j'_2 k \ell_k) \Bigg]^2$$

$$+ \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \sum_{a_1} \Bigg[\sum_{QLS\,Q'L'S'} \sum C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q'_J L'_J S'_J)$$
$$\times N(j_1 j_2) N(j_1 j'_2) f^{a_1}_\ell(j_2 j'_2; LSJ, L'S'J'; j_1 \tfrac{1}{2}) \Re_\ell(q\ell_q n_2 j_2; k\ell_k n'_2 j'_2) \Bigg]^2$$

(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):

$$\sigma(j_1 j_2[L_{12}S_{12}]j_3 L_J S_J J, j_1' j_2'[L_{12}'S_{12}']j_3' L_J' S_J' J') =$$

$$= \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \left| \sum_{n_3 \ell_3 n_3' \ell_3'} \sum_{QLSQ'L'S'} C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q_J' L_J' S_J') \right.$$

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

$$f_\ell(\ell_3 \ell_3'; LSJ, L'S'J'; L_{12}'') P_\ell(q\ell_q n_3 \ell_3; n_3' \ell_3' k \ell_k)$$

$$\times \left(\frac{2}{2\ell+1} P_\ell(q\ell_q n_3 \ell_3; n_3' \ell_3' k \ell_k) - \sum_{\ell'} (-1)^{\ell+\ell'} P_\ell(q\ell_q n_3 \ell_3; k\ell_k n_3' \ell_3') \begin{Bmatrix} \ell_3' & \ell_3 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \right)^2$$

$$+ \frac{A_0}{(2J+!)} \sum_{\ell_q \ell_k} \sum_{\ell} \sum_{a_1 a_2} \left| \sum_{\ell'} \sum_{n_3 \ell_3 n_3' \ell_3'} \sum_{QLSQ'L'S'} C^J(QLS, Q_J L_J S_J) C^{J'}(Q'L'S', Q_J' L_J' S_J') \right.$$

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

$$\left. \times f_\ell^{a_1 a_2}((\ell_3 \ell_3'; LSJ, L'S'J'; L_{12}''S_{12}'')(-1)^{\ell+\ell'} P_{\ell'}(q\ell_q n_3 \ell_3; k\ell_k n_3' \ell_3') \begin{Bmatrix} \ell_3' & \ell_3 & \ell \\ \ell_k & \ell_q & \ell' \end{Bmatrix} \right)^2 \quad \text{(B.1)}$$

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

$$f_\ell(\ell_3 \ell_3'; LSJ, L'S'J', L_{12}'') = (-1)^{L_{12}''} \sqrt{(2L+1)(2L'+1)} \begin{Bmatrix} L & L' & \ell \\ \ell_3' & \ell_3 & L_{12}'' \end{Bmatrix}$$

$$\times (-1)^{-S+\ell+J} \delta(S,S') \sqrt{(2J+1)(2J'+1)} \begin{Bmatrix} J & J' & \ell \\ L' & L & S \end{Bmatrix} \quad \text{(B.2)}$$

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

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

$$\times\begin{Bmatrix} L & L' & \ell \\ \ell'_3 & \ell_3 & L''_{12} \end{Bmatrix}\begin{Bmatrix} a_2 & 1/2 & 1/2 \\ S''_{12} & S & S' \end{Bmatrix}\begin{Bmatrix} J & \ell & a_1 \\ L' & S & L \end{Bmatrix}\begin{Bmatrix} a_1 & J' & a_2 \\ S' & S & L' \end{Bmatrix} \tag{B.3}$$

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 $L_{12}S_{12}$

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

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

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

$$\times\Big(P_{L''_{12}S''_{12}}(\ell_1 j_3, \ell_2 j_2)\delta(\ell_3, j_1)\begin{Bmatrix} j_3 & j_2 & L''_{12} \\ j_1 & L & L_{12} \end{Bmatrix}$$

$$-P_{L''_{12}S''_{12}}(\ell_1 j_3, \ell_2 j_1)\delta(\ell_3, j_2)(-1)^{j_1+j_2+L_{12}+S_{12}}\begin{Bmatrix} j_3 & j_1 & L''_{12} \\ j_2 & L & L_{12} \end{Bmatrix}\Big)\Big] \tag{B.4}$$

where P defines two-electron system and equal to

$$P_{L''_{12}S''_{12}}(\ell_1 j_1, \ell_2 j_2) = \delta(\ell_1, j_1)\delta(\ell_2, j_2) + \delta(\ell_1, j_2)\delta(\ell_2, j_1) \tag{B.5}$$

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

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

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/√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/√2). Let us consider

$$\frac{1}{2}\sum_{\ell_1\ell_2} C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3}(L_{12}S_{12}, L''_{12}S''_{12}; LS)C_{\ell_1 j'_1 \ell_2 j'_2 \ell'_3 j'_3}(LS, L''_{12}S''_{12}; L'S') \tag{B.7}$$

After simple but cumbersome calculations we obtain for this expression

$$\frac{1}{2}\sum_{\ell_1\ell_2} C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3}(L_{12}S_{12}, L''_{12}S''_{12}; LS) C_{\ell_1 j'_1 \ell_2 j'_2 \ell'_3 j'_3}(L'_{12}S'_{12}, L''_{12}S''_{12}; L'S') =$$
$$= N(j_1 j_2 j_3) N(j'_1 j'_2 j'_3)[A_1 + A_2 + A_3]$$

(B.8)

where

$$A_2 = \delta(L_{12}, L''_{12})\delta(S_{12}, S''_{12})\sqrt{(2L'_{12}+1)(2S'_{12}+1)(2L''_{12}+1)(2S''_{12}+1)}$$
$$\times \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \Bigg[P_{L''_{12}S''_{12}}(j_1 j_2, j'_3 j'_2)\delta(\ell_3, j_3)\delta(\ell'_3, j'_1) \begin{Bmatrix} j'_3 & j'_2 & L''_{12} \\ j'_1 & L' & L'_{12} \end{Bmatrix}$$
$$+ P_{L''_{12}S''_{12}}(j_1 j_2, j'_3 j'_2)\delta(\ell_3, j_3)\delta(\ell'_3, j'_2) \begin{Bmatrix} j'_3 & j'_1 & L''_{12} \\ j'_2 & L' & L'_{12} \end{Bmatrix} (-1)^{j'_1 + j'_2 + L'_{12} + S'_{12}} \Bigg]$$
$$+\delta(L'_{12}, L''_{12})\delta(S'_{12}, S''_{12})\sqrt{(2L_{12}+1)(2S_{12}+1)(2L''_{12}+1)(2S''_{12}+1)} \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S_{12} & S \end{Bmatrix}$$
$$\times \Bigg[P_{L''_{12}S''_{12}}(j_3 j_2, j'_1 j'_2)\delta(\ell_3, j_1)\delta(\ell'_3, j'_3) \begin{Bmatrix} j_3 & j_2 & L''_{12} \\ j_1 & L & L_{12} \end{Bmatrix}$$
$$+ P_{L''_{12}S''_{12}}(j_3 j_1, j'_1 j'_2)\delta(\ell_3, j_2)\delta(\ell'_3, j'_3) \begin{Bmatrix} j_3 & j_2 & L''_{12} \\ j_1 & L & L_{12} \end{Bmatrix} (-1)^{j_1 + j_2 + L_{12} + S_{12}} \Bigg]$$

(B.9)

$$A_3 = (2L''_{12}+1)(2S''_{12}+1)\sqrt{2L_{12}+1)(2S_{12}+1)(2L'_{12}+1)(2S'_{12}+1)}$$
$$\times \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S_{12} & S \end{Bmatrix} \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix}$$
$$\times \Bigg[P_{L''_{12}S''_{12}}(j_3 j_2, j'_3 j'_2)\delta(\ell_3, j_1)\delta(\ell'_3, j'_1) \begin{Bmatrix} j_3 & j_2 & L''_{12} \\ j_1 & L & L_{12} \end{Bmatrix} \begin{Bmatrix} j'_3 & j'_2 & L''_{12} \\ j'_1 & L' & L'_{12} \end{Bmatrix}$$
$$+ P_{L''_{12}S''_{12}}(j_3 j_2, j'_3 j'_1)\delta(\ell_3, j_1)\delta(\ell'_3, j'_2) \begin{Bmatrix} j_3 & j_2 & L''_{12} \\ j_1 & L & L_{12} \end{Bmatrix} \begin{Bmatrix} j'_3 & j'_1 & L''_{12} \\ j'_2 & L' & L'_{12} \end{Bmatrix} (-1)^{j'_1 + j'_2 + L'_{12} + S'_{12}}$$
$$+ P_{L''_{12}S''_{12}}(j_3 j_1, j'_3 j'_2)\delta(\ell_3, j_2)\delta(\ell'_3, j'_1) \begin{Bmatrix} j_3 & j_1 & L''_{12} \\ j_2 & L & L_{12} \end{Bmatrix} \begin{Bmatrix} j'_3 & j'_2 & L''_{12} \\ j'_1 & L' & L'_{12} \end{Bmatrix} (-1)^{j_1 + j_2 + L_{12} + S_{12}}$$
$$+ P_{L''_{12}S''_{12}}(j_3 j_1, j'_3 j'_1)\delta(\ell_3, j_2)\delta(\ell'_3, j'_2) \begin{Bmatrix} j_3 & j_1 & L''_{12} \\ j_2 & L & L_{12} \end{Bmatrix} \begin{Bmatrix} j'_3 & j'_1 & L''_{12} \\ j'_2 & L' & L'_{12} \end{Bmatrix}$$
$$\times (-1)^{j_1 + j_2 + j'_1 + j'_2 + L_{12} + S_{12} + L'_{12} + S'_{12}} \Bigg]$$

(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 ($1s^2[^1S]2s\ ^2S$- $2p2s[^{1,3}P]1s\ ^{2,4}P$ 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

$$\frac{1}{2}\sum_{\ell_1\ell_2} C_{\ell_1 j_1^0 \ell_2 j_1^0 \ell_3 j_2^0}(L_{12}S_{12}, L''_{12}S''_{12}; LS) C_{\ell_1 j_3^0 \ell_2 j_2^0 \ell'_3 j_1^0}(L'_{12}S'_{12}, L''_{12}S''_{12}; L'S') =$$

$$= (2L''_{12}+1)(2S''_{12}+1)\sqrt{2(2L_{12}+1)(2S_{12}+1)(2L'_{12}+1)(2S'_{12}+1)} \times \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S_{12} & S \end{Bmatrix} \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \begin{Bmatrix} j_2^0 & j_1^0 & L''_{12} \\ j_1^0 & L & L_{12} \end{Bmatrix} \begin{Bmatrix} j_1^0 & j_2^0 & L''_{12} \\ j_3^0 & L' & L'_{12} \end{Bmatrix} \times \delta(\ell_3, j_1^0)\delta(\ell'_3, j_3^0)(-1)^{j_1^0+j_2^0+L''_{12}+S''_{12}} \quad \text{(B.13)}$$

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 $j'_1 = j'_2 = j_2^0, j'_3 = j_1^0$ we obtain for sum over l_1, l_2

$$\frac{1}{2}\sum_{\ell_1\ell_2} C_{\ell_1 j_1^0 \ell_2 j_1^0 \ell_3 j_2^0}(L_{12}S_{12}, L''_{12}S''_{12}; LS) C_{\ell_1 j_2^0 \ell_2 j_2^0 \ell'_3 j_1^0}(L'_{12}S'_{12}, L''_{12}S''_{12}; L'S') =$$

$$= 2(2L''_{12}+1)(2S''_{12}+1)\sqrt{(2L_{12}+1)(2S_{12}+1)(2L'_{12}+1)(2S'_{12}+1)}$$
$$\times \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S_{12} & S \end{Bmatrix} \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \begin{Bmatrix} j^0_2 & j^0_1 & L''_{12} \\ j^0_1 & L & L_{12} \end{Bmatrix} \begin{Bmatrix} j^0_1 & j^0_2 & L''_{12} \\ j^0_2 & L' & L'_{12} \end{Bmatrix}$$
$$\times \delta(\ell_3, j^0_1)\delta(\ell'_3, j^0_2)(-1)^{j^0_1+j^0_2+L''_{12}+S''_{12}} \qquad \text{(B.14)}$$

These formulas can be simplified in the case of $j^0_1 = 0$ 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):

$$\frac{1}{2}\sum_{\ell_1\ell_2} C_{\ell_1 0 \ell_2 j^0 \ell_3 j^0_2}(00, L''_{12}S''_{12}; LS) C_{\ell_1 j^0_3 \ell_2 j'^0_2 \ell'_3 0}(L'_{12}S'_{12}, L''_{12}S''_{12}; L'S') =$$
$$= \frac{1}{\sqrt{2}}(2S''_{12}+1)\sqrt{2S'_{12}+1} \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} (-1)^{j^0_2+j^0_3+L'+1}$$
$$\times \delta(j^0_2, L)\delta(j^0_2, L''_{12})\delta(L'_{12}, L')\delta(\ell_3, 0)\delta(\ell'_3, j^0_3) \qquad \text{(B.15)}$$

$$\frac{1}{2}\sum_{\ell_1\ell_2} C_{\ell_1 0 \ell_2 j^0 \ell_3 j^0_2}(00, L''_{12}S''_{12}; LS) C_{\ell_1 j^0_2 \ell_2 j'^0_2 \ell'_3 0}(L'_{12}S'_{12}, L''_{12}S''_{12}; L'S') =$$
$$= (2S''_{12}+1)\sqrt{2S'_{12}+1} \begin{Bmatrix} 1/2 & S''_{12} & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} (-1)^{L'+1}$$
$$\times \delta(j^0_2, L)\delta(j^0_2, L''_{12})\delta(L'_{12}, L')\delta(\ell_3, 0)\delta(\ell'_3, j^0_2) \qquad \text{(B.16)}$$

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

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

$$Y^{a_1a_2}_\ell(\ell_3\ell'_3; j_1 j_2[L_{12}S_{12}]j_3 LSJ, j'_1 j'_2[L'_{12}S'_{12}]j'_3 L'S'J') =$$
$$\times \frac{1}{2}\sum_{L''_{12}S''_{12}} \sum_{\ell_1\ell_2} C_{\ell_1 j_1 \ell_2 j_2 \ell_3 j_3}(L_{12}S_{12}, L''_{12}S''_{12}; LS) C_{\ell_1 j'_1 \ell_2 j'_2 \ell'_3 j'_3}(LS, L''_{12}S''_{12}; L'S')$$
$$f^{a_1a_2}_\ell(\ell_3\ell'_3; LSJ, L'S'J'; L''_{12}S''_{12}) \qquad \text{(B.18)}$$

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:

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

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

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

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

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

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

$$\begin{aligned}&Y_\ell^{a_1a_2}(\ell_3\ell'_3;1s^2[^1S]j_2^0\ LSJ,j_3^0j_2^0[L'_{12}S'_{12}]ls\ L'S'J')=\\&=\sqrt{(2S'_{12}+1)(2a_1+1)(2a_2+1)(2L'+1)(2S+1)(2S'+1)(2J+1)(2J'+1)/2}\\&\times(-1)^{2a_1+S'-1/2+L+L'-J+J'}\begin{Bmatrix}1/2 & a_2 & 1/2\\ 1/2 & S'_{12} & S'\end{Bmatrix}\begin{Bmatrix}J & j_3^0 & a_1\\ L' & S & L\end{Bmatrix}\begin{Bmatrix}a_1 & J' & a_2\\ S' & S & L'\end{Bmatrix}\\&\times\delta(j_2^0,L)\delta(j_3^0,\ell)\delta(L'_{12},L')\delta(\ell_3,0)\delta(\ell'_3,j_3^0)\end{aligned} \tag{B.24}$$

$$Y_\ell^{a_1a_2}(\ell_3\ell'_3;1s^2[^1S]j_2^0\ LSJ, j_2^0 j_2^0[L'_{12}S'_{12}]ls\ L'S'J') =$$
$$= \sqrt{(2S'_{12}+1)(2a_1+1)(2a_2+1)(2L'+1)(2S+1)(2S'+1)(2J+1)(2J'+1)}$$
$$\times(-1)^{2a_1+S'-1/2+L+L'-J+J'} \begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \begin{Bmatrix} J & j_2^0 & a_1 \\ L' & S & L \end{Bmatrix} \begin{Bmatrix} a_1 & J' & a_2 \\ S' & S & L' \end{Bmatrix}$$
$$\times\delta(j_2^0,L)\delta(j_2^0,\ell)\delta(L'_{12},L')\delta(\ell_3,0)\delta(\ell'_3,j_2^0) \qquad \text{(B.25)}$$

These formulas allow us to calculate all angular coefficients for our special cases: ($1s^2[^1S]2s\ ^2S$- $2p2s[^{1,3}P]1s\ ^{2,4}P$ and $1s^2[^1S]2l\ ^2l$ - $2l^2[L'_{12}S'_{12}]1s\ L'S'$) with l=0,1.

Let us consider $1s^2[^1S]2s\ ^2S$- $2p2s[^{1,3}P]1s\ ^{2,4}P$ excitation. For this special case we obtain from eqs.(B.22), (B.24):

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

$$Y_\ell^{a_1a_2}(\ell_3\ell'_3;1s^2[^1S]2s\ ^2S_{1/2},2p2s[1S'_{12}]ls\ 1S'J') =$$
$$= \sqrt{(2S'_{12}+1)(2a_1+1)(2a_2+1)(2S'+1)(2J'+1)}$$
$$\times(-1)^{a_1+S'+1/2+J'} \begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix} \begin{Bmatrix} a_1 & J' & a_2 \\ S' & 1/2 & 1 \end{Bmatrix} \delta(\ell,1)\delta(\ell_3,0)\delta(\ell'_3,1) \qquad \text{(B.27)}$$

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:

$$\sum_{a_1}\sum_{a_2}\left[Y_\ell^{a_1a_2}(\ell_3\ell'_3;1s^2[^1S]2s\ ^2S_{1/2},2p2s[1S'_{12}]ls\ 1S'J')\right]^2 = (2J'+1)\delta(\ell,1)\delta(\ell_3,0)\delta(\ell'_3,1) \qquad \text{(B.28)}$$

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

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

$$Y_\ell^{a_1a_2}(\ell_3\ell'_3;1s^2[^1S]2s\ ^2S_{1/2},2s^2[^1S]ls\ ^2S_{1/2}) = \sqrt{(2a_2+1)}\delta(a_1,\frac{1}{2})\delta(\ell,0)\delta(\ell_3,0)\delta(\ell'_3,0)$$
$$\text{(B.30)}$$

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

$$\sum_{a_1}\sum_{a_2}\left[Y_\ell^{a_1a_2}(\ell_3\ell'_3;1s^2[^1S]2s\ ^2S_{1/2},2s^2[^1S]1s\ ^2S_{1/2})\right]^2 = 4\delta(\ell,0)\delta(\ell_3,0)\delta(\ell'_3,0) \tag{B.31}$$

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

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

$$Y_\ell^{a_1a_2}(\ell_3\ell'_3;1s^2[^1S]2p\ 1\tfrac{1}{2}J,2p^2[L'_{12}S'_{12}]1s\ L'S'J') = \delta(\ell,1)\delta(L'_{12},L')\delta(\ell_3,0)\delta(\ell'_3,1)$$
$$= \sqrt{2(2S'_{12}+1)(2a_1+1)(2a_2+1)(2L'+1)(2S'+1)(2J+1)(2J'+1)}$$
$$\times(-1)^{2a_1+1/2+L'+S'-J+J'}\begin{Bmatrix} 1/2 & a_2 & 1/2 \\ 1/2 & S'_{12} & S' \end{Bmatrix}\begin{Bmatrix} J & 1 & a_1 \\ L' & 1/2 & L \end{Bmatrix}\begin{Bmatrix} a_1 & J' & a_2 \\ S' & 1/2 & L' \end{Bmatrix} \tag{B.33}$$

Table1a.Energy of *1s2l2l'* states counted from $1s^2 2s$ in unit 10^4 cm^{-1}

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

Z	C232 -S212	C234 -S212	K232 -S212	K234 -S212	K432 -S212	K434 -S212	K436 -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

Table1b.Energy of *1s2l2l'* 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 -S212	M432 -S212	M232 -S212	F212 -S212	M434 -S212	M234 -S212	F254 -S212	M436 -S212	F256 -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 $1s^2 2s\ ^2S_{1/2}$ and $1s2s\ ^3S_1$ 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 $1s2s\ (^3S_1)$ 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
$1s^2[^1S]2s\ ^2S_{1/2}$-$2p2s(^1P)1s\ ^2P_{1/2}$ S212 -C232	0.167	0.232	0.167	0.167
$1s^2[^1S]2s\ ^2S_{1/2}$-$2p2s(^3P)1s\ ^2P_{1/2}$ S212 -K232	0.5	0.426	0.167	0.167
$1s^2[^1S]2s\ ^2S_{1/2}$-$2p2s(^3P)1s\ ^4P_{1/2}$ S212 -K432	0	0.007	0.167	0.167
$1s^2[^1S]2s\ ^2S_{1/2}$-$2p2s(^1P)1s\ ^2P_{3/2}$ S212 -C234	0.333	0.002	0.333	0.333
$1s^2[^1S]2s\ ^2S_{1/2}$-$2p2s(^3P)1s\ ^2P_{3/2}$ S212 -K234	1.0	1.29	0.333	0.333
$1s^2[^1S]2s\ ^2S_{1/2}$-$2p2s(^3P)1s\ ^4P_{3/2}$ S212 -K434	0	0.043	0.333	0.333
$1s^2[^1S]2s\ ^2S_{1/2}$-$2p2s(^3P)1s\ ^4P_{5/2}$ S212 -K436	0	0	0.5	0.5

b) 1s-2s excitation

Transitions	N'_l	A'_l	N''_l	A''_l
$1s^2[^1S]2s\ ^2S_{1/2}$-$2s^2(^1S)1s\ ^2S_{1/2}$ S212 -E212	1.0	0.923	1.0	0.923
$1s^2[^1S]2s\ ^2S_{1/2}$-$2p^2(^3P)1s\ ^2P_{1/2}$ S212 -M232	0	0.0048	0	0.0048
$1s^2[^1S]2s\ ^2S_{1/2}$-$2p^2(^1S)1s\ ^2S_{1/2}$ S212 -F212	0	0.0610	0	0.0610
$1s^2[^1S]2s\ ^2S_{1/2}$-$2p^2(^3P)1s\ ^4P_{1/2}$ 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(^{1}P)1s, K=2s2p(^{3}P)1s, S=1s^{2}2s,

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=$2s^2(^1S)1s$, M=$2p^2(^3P)1s$, F=$2p^2(^1S)1s$, F=$2p^2(^1D)1s$, S=$1s^22s$, P=$1s^22p$

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	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	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 $1s^2 2s$ - $1s2s2p$ excitation of Li-like ions:

$$\sigma=\sigma_C x\frac{a_0^2}{Z_S^4}\ (cm^2),\ E=13.6Z_S^2(\Delta\varepsilon+u)\ (ev)$$

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

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

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

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: $\sigma=\sigma_C x\frac{a_0^2}{Z_S^4}$ (cm^2), $E=13.6Z_S^2(\Delta\varepsilon+u)$ (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 $1s^22s$ - $1s2s2p$ excitation of Li-like ions:

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

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

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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	0.8265	0.8222	0.8283	0.8277	0.8195	0.8242

Table 7. Rate coefficients 1s-2s excitation ($\mathbf{R_C}$) for emission lines $1s^22p$ -$1s2s^2$, $1s^22p$ -$1s2p^2$ of Li-like ions: $R = 10^{-8}\frac{R_C}{Z_S^3}\exp(-\beta\Delta\varepsilon)$ in cm^3/s

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
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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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	12/14	12/14	12/14	12/14	12/14	12/14	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
Δε	0.9290	0.9290	0.9598	0.9598	0.9526	0.9526	0.9452	0.9452
Z_S/Z_N	14/16	14/16	14/16	14/16	14/16	14/16	14/16	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
Δε	0.9031	0.9031	0.9297	0.9297	0.9236	0.9236	0.9170	0.9170
Z_S/Z_N	18/20	18/20	18/20	18/20	18/20	18/20	18/20	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
Δε	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	20/22	20/22	20/22	20/22	20/22	20/22	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
Δε	0.8584	0.8584	0.8783	0.8783	0.8735	0.8735	0.8686	0.8686
Z_S/Z_N	24/26	24/26	24/26	24/26	24/26	24/26	24/26	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
Δε	0.8423	0.8423	0.8604	0.8604	0.8556	0.8556	0.8513	0.8513
Z_S/Z_N	26/28	26/28	26/28	26/28	26/28	26/28	26/28	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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
Δε	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 calcultions, b- data by Bely-Dubau et al [4].

Designations are from Table 4 and 5.

	a	b	a	b	a	b
T (10^6 K)	**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		**u**		**v**	
5.0	2.88-19	2.39-19	3.19-19	3.14-19	1.50-19	1.53-19
7.5	4.22-17		4.44-17		2.08-17	
10	4.93-16	4.05-16	4.94-16	4.79-16	2.30-16	2.28-16
15	5.56-15	4.57-15	5.08-15	4.89-15	2.33-15	2.29-15
20	1.83-14	1.51-14	1.54-14	1.47-14	6.95-15	6.75-15
30	5.90-14	4.85-14	4.29-14	4.05-14	1.88-14	1.80-14
40	1.04-13	8.61-14	6.73-14	6.30-14	2.87-14	2.72-14
60	1.74-13	1.52-13	9.21-14	9.02-14	3.71-14	3.67-14
80	2.41-13	2.00-13	1.11-13	1.02-13	4.22-14	3.94-14
100	2.85-13	2.35-13	1.19-13	1.07-13	4.36-14	3.92-14
120	3.16-13		1.18-13		4.11-14	
160	3.59-13		1.16-13		3.76-14	

Table 9 (continued)

	a	b	a	b	a	b	a	b
T (10^6 K)		**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 (σ c) for the six $2s2p(^{1,3}P)1s\ ^{2,4}P_J$ - $1s^22s\ ^2S_{1/2}$ 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 = $2s2p(^3P)1s\ ^2P_{2/3}$ - $1s^22s\ ^2S_{1/2}$

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

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

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

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

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

Fig.2. Scaled cross section (σ c) 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 = $2s^21s\ ^2S_{1/2}$ - $1s^22p\ ^2P_{3/2}$

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

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

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

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

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

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

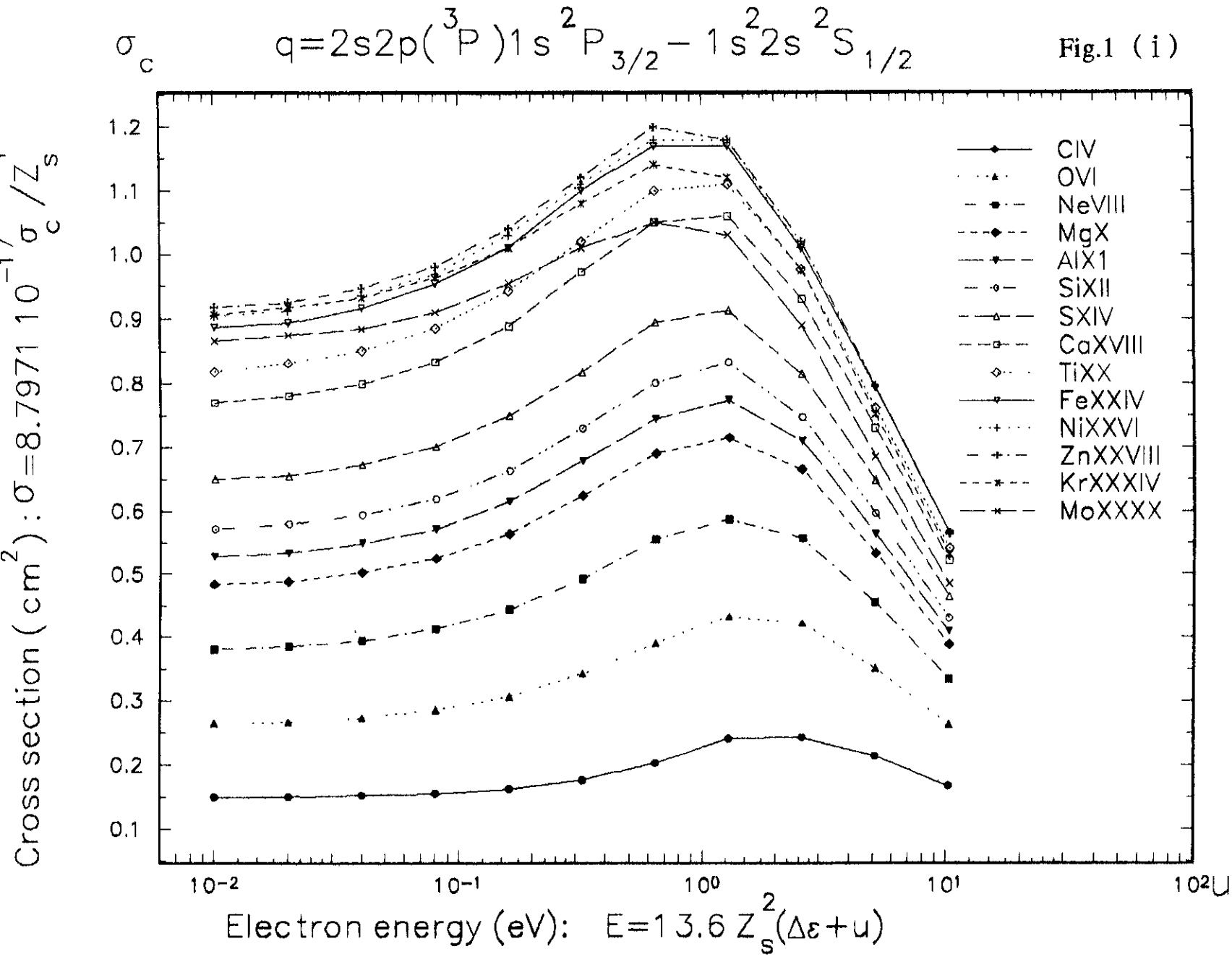
(viii) i = $2p^21s\ ^4P_{1/2}$ - $1s^22p\ ^2P_{1/2}$

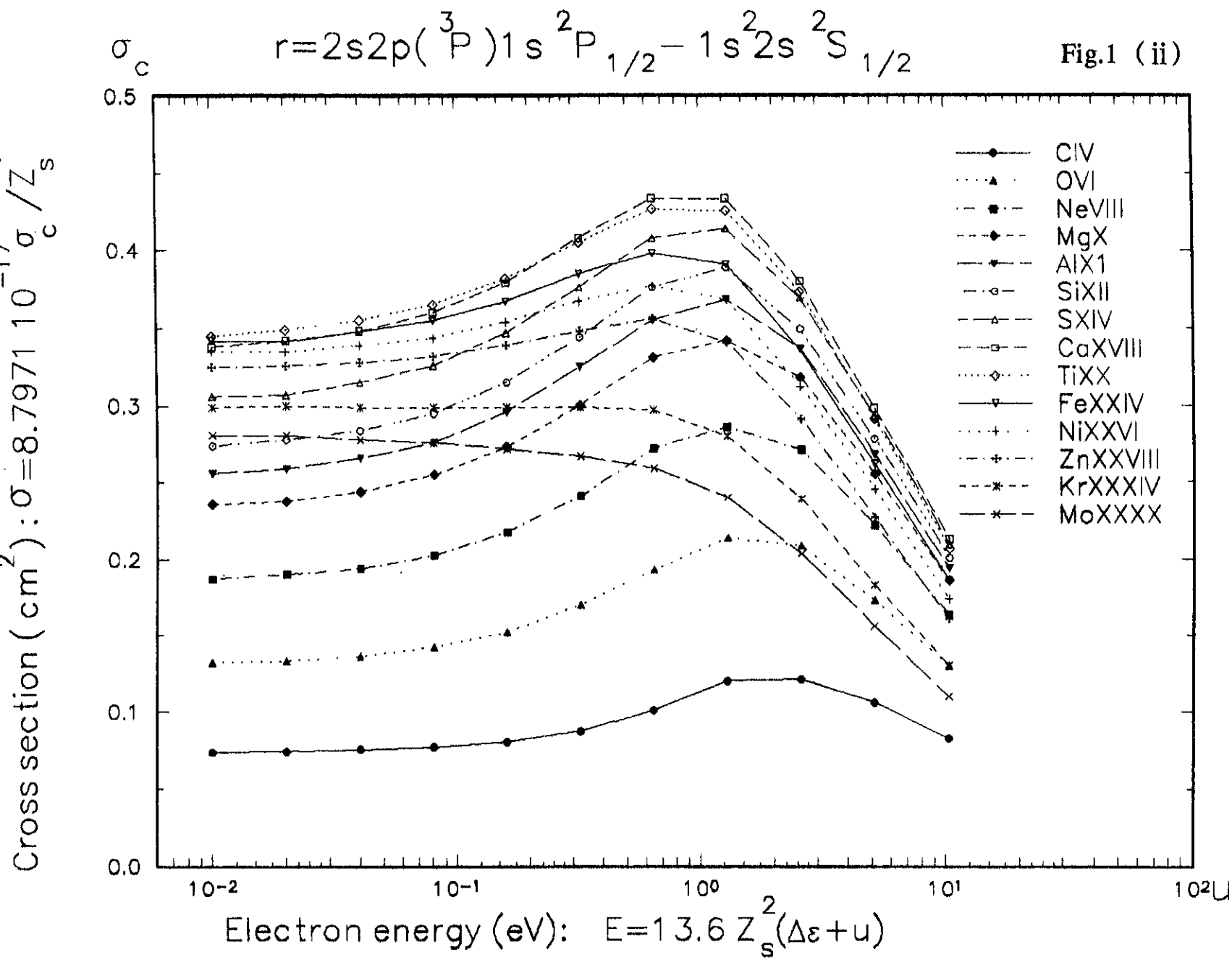
Fig.3. Scaled excitation rate coefficients (**Rc**) for the six $2s2p(^{1,3}P)1s\ ^{2,4}P_J$ - $1s^2\ 2s\ ^2S_{1/2}$ lines of Li-like ions with Z = 6, 8, 10, 12, 13, 16, 20, 22, 26, 28, 30, 36 and 42 as function of the scaled electron temperature 1/ β in nuits of Zs^2 (Ry), where Zs = Z-2.

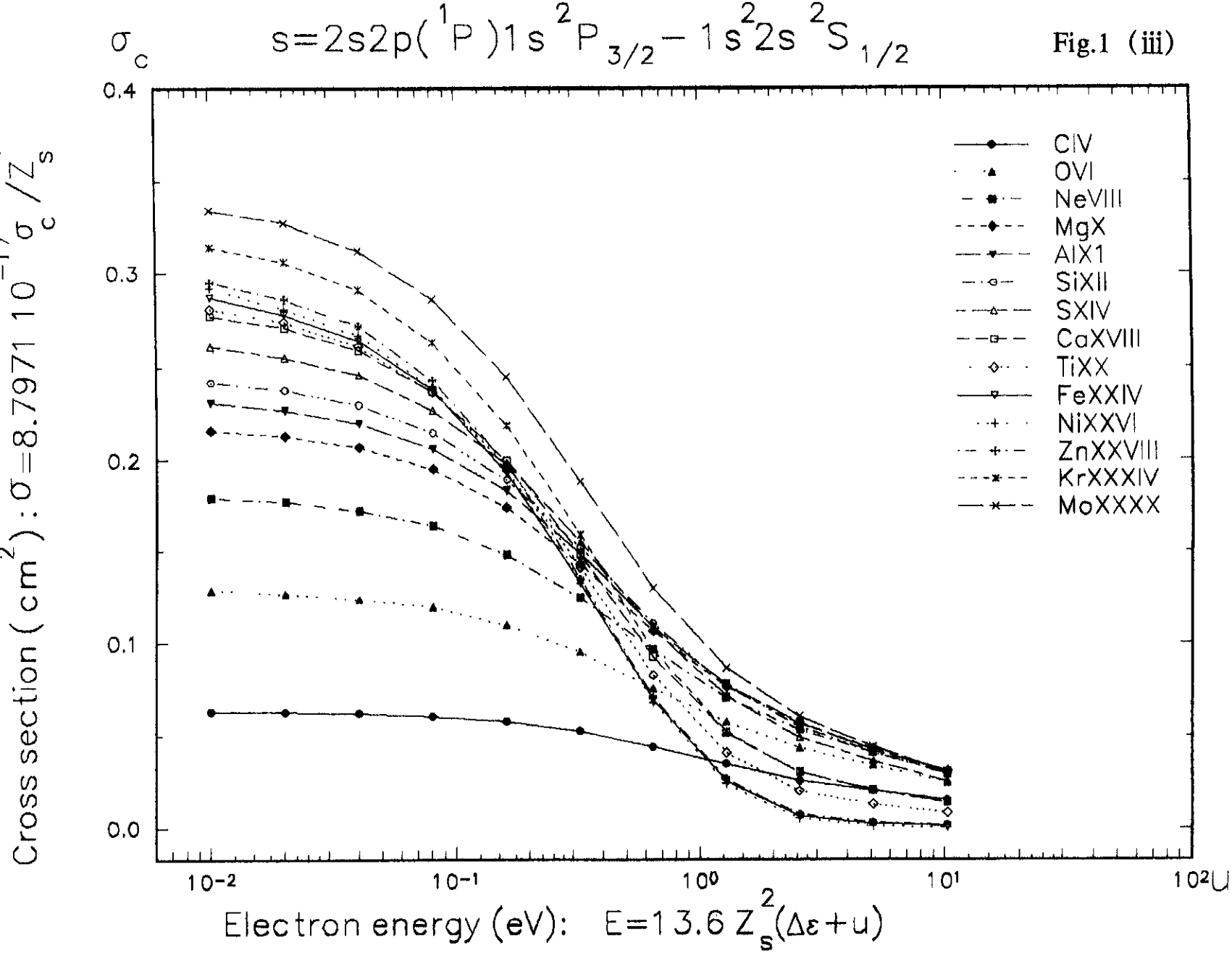
(i) - (vi) ; the same transitions as in Fig.1

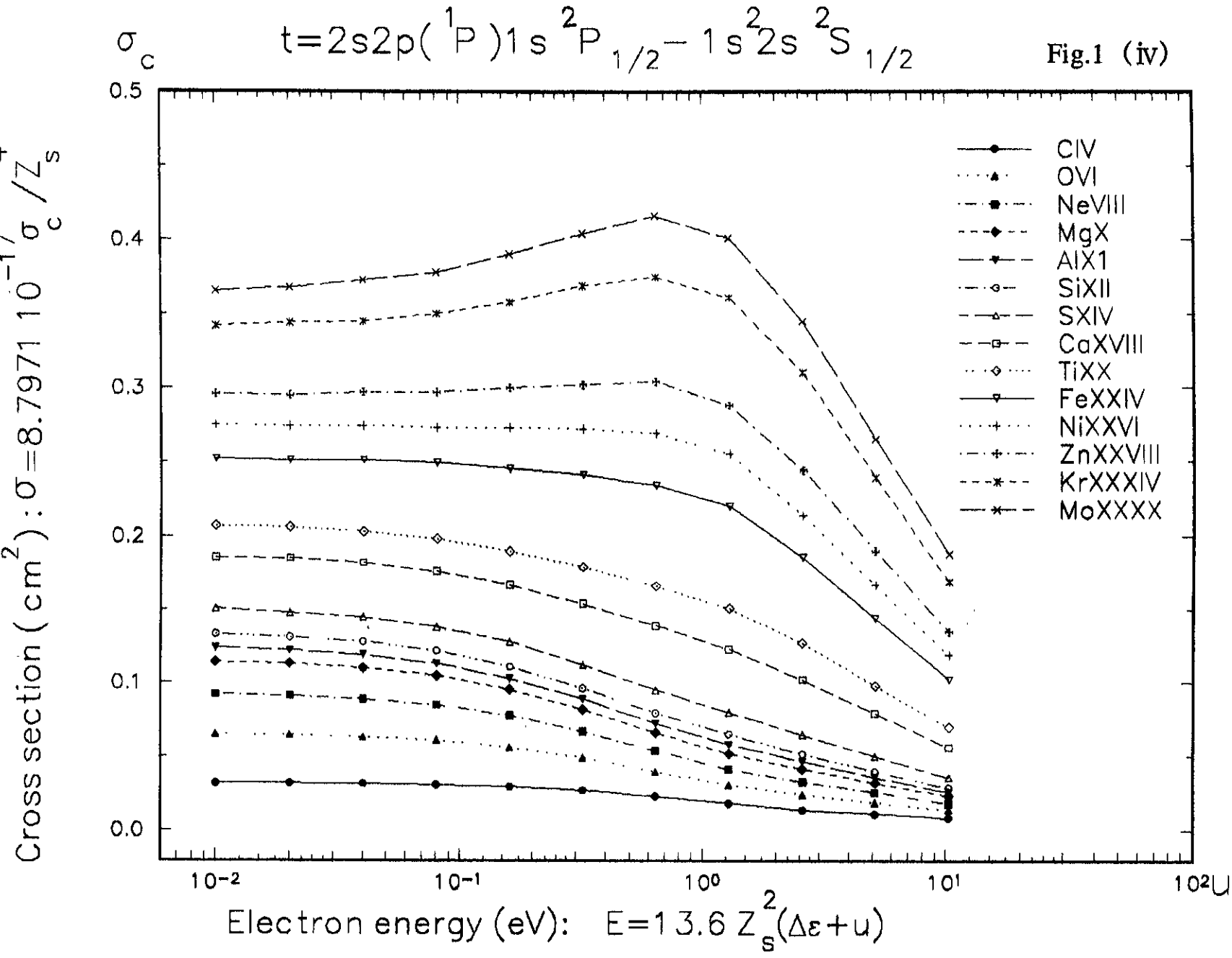
Fig.4. Scaled excitation rate coefficients (Rc) for the eight emissionlines $1s^22p$ - $1s2s^2$, $1s^22p$ - $1s2p^2$ of Li-like ions with Z = 6, 8, 10, 12, 13, 16, 20, 22, 26, 28, 30, 36 and 42 as function of the scaled electron temperature 1/ β in nuits of Zs^2 (Ry), where Zs = Z-2.

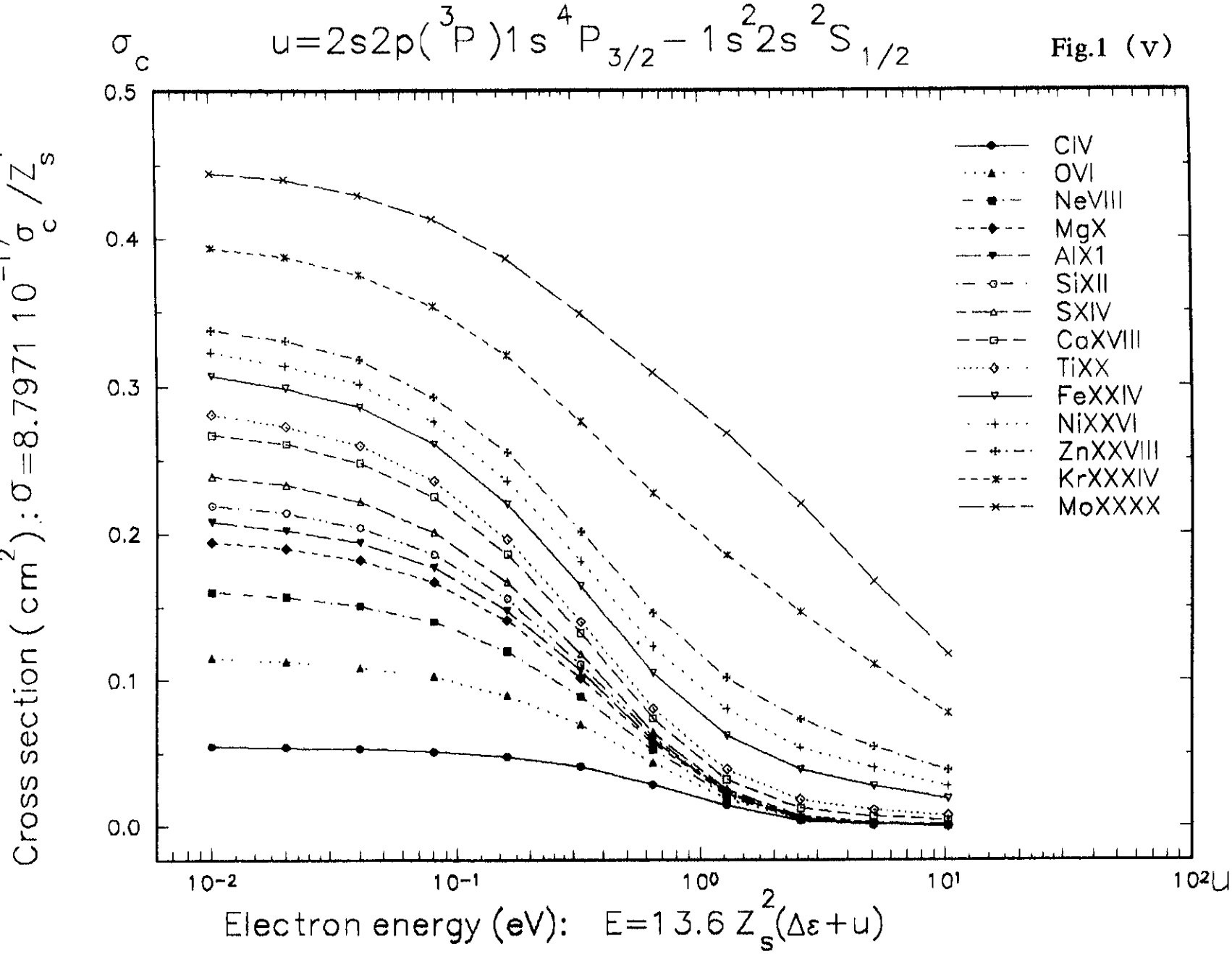
(i) - (viii) ; the same transitions as in Fig.2.

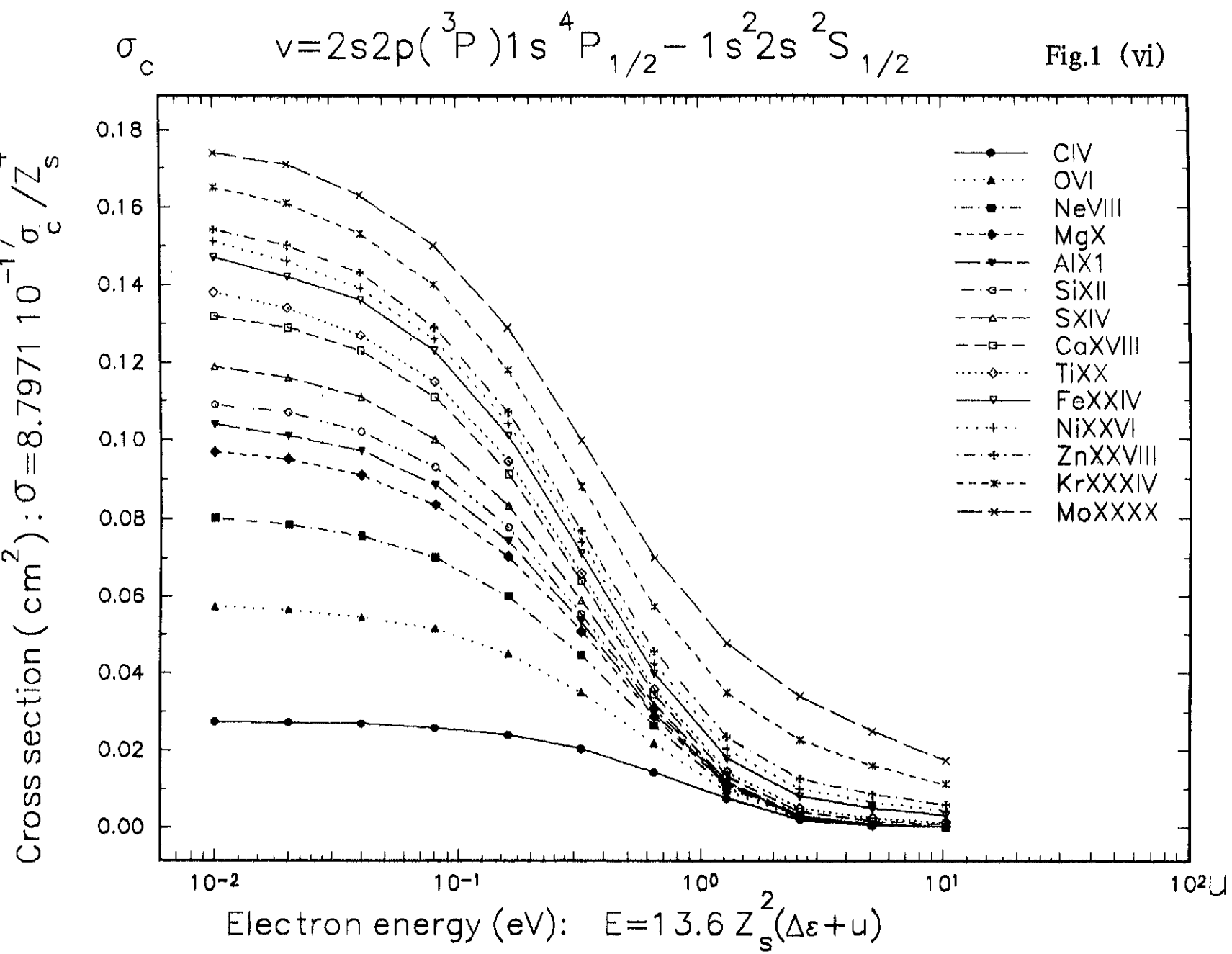

σc
q=2s2p(3P)1s 2P3/2 − 1s22s 2S1/2
Fig.1 (i)
Cross section (cm2): σ=8.7971 10−17 σc /Zs4
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
10−2
10−1
100
101
102U
Electron energy (eV): E=13.6 Zs2(Δε+u)
CIV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


σc
r=2s2p(3P)1s 2P1/2 − 1s22s 2S1/2
Fig.1 (ii)
Cross section (cm2): σ=8.7971 10−17 σc /Zs4
0.5
0.4
0.3
0.2
0.1
0.0
10-2
10-1
100
101
102U
Electron energy (eV): E=13.6 Zs2(Δε+u)
ClV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


σc s=2s2p(1P)1s2P3/2−1s22s2S1/2
Fig.1 (iii)
Cross section (cm2): σ=8.7971 10−17 σc /Zs4
0.4
0.3
0.2
0.1
0.0
10-2
10-1
100
101
102U
Electron energy (eV): E=13.6 Zs2(Δε+u)
CIV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


σc
t=2s2p(1P)1s 2P1/2 – 1s22s 2S1/2
Fig.1 (iv)
Cross section (cm2): σ=8.7971 10-17 σc /Zs4
0.5
0.4
0.3
0.2
0.1
0.0
10-2
10-1
100
101
102U
Electron energy (eV): E=13.6 Zs2(Δε+u)
ClV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


σc
u=2s2p(3P)1s 4P3/2 − 1s2 2s 2S1/2
Fig.1 (v)
Cross section (cm2): σ=8.7971 10−17 σc /Zs4
0.5
0.4
0.3
0.2
0.1
0.0
10-2
10-1
100
101
102U
Electron energy (eV): E=13.6 Zs2(Δε+u)
CIV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


σc v=2s2p(3P)1s 4P1/2 − 1s22s 2S1/2
Fig.1 (vi)
Cross section (cm2): σ=8.7971 10−17 σc /Zs4
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
10-2
10-1
100
101
102U
Electron energy (eV): E=13.6 Zs2(Δε+u)
CIV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

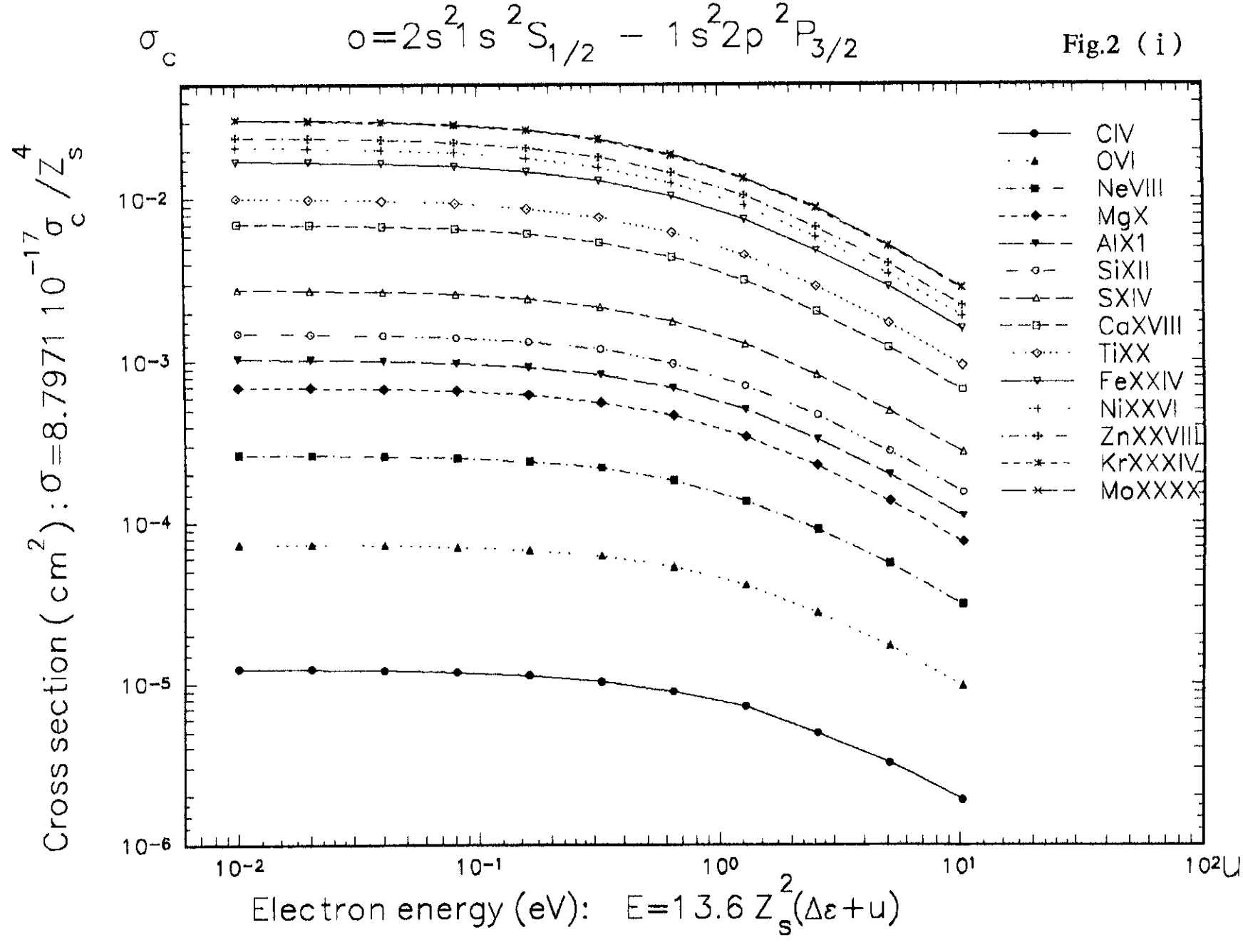

σc
o=2s²1s ²S1/2 − 1s²2p ²P3/2
Cross section (cm²): σ=8.7971 10⁻¹⁷ σc /Zs⁴
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻²
10⁻¹
10⁰
10¹
10²U
Electron energy (eV): E=13.6 Zs²(Δε+u)
CIV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

Fig.2 (i)

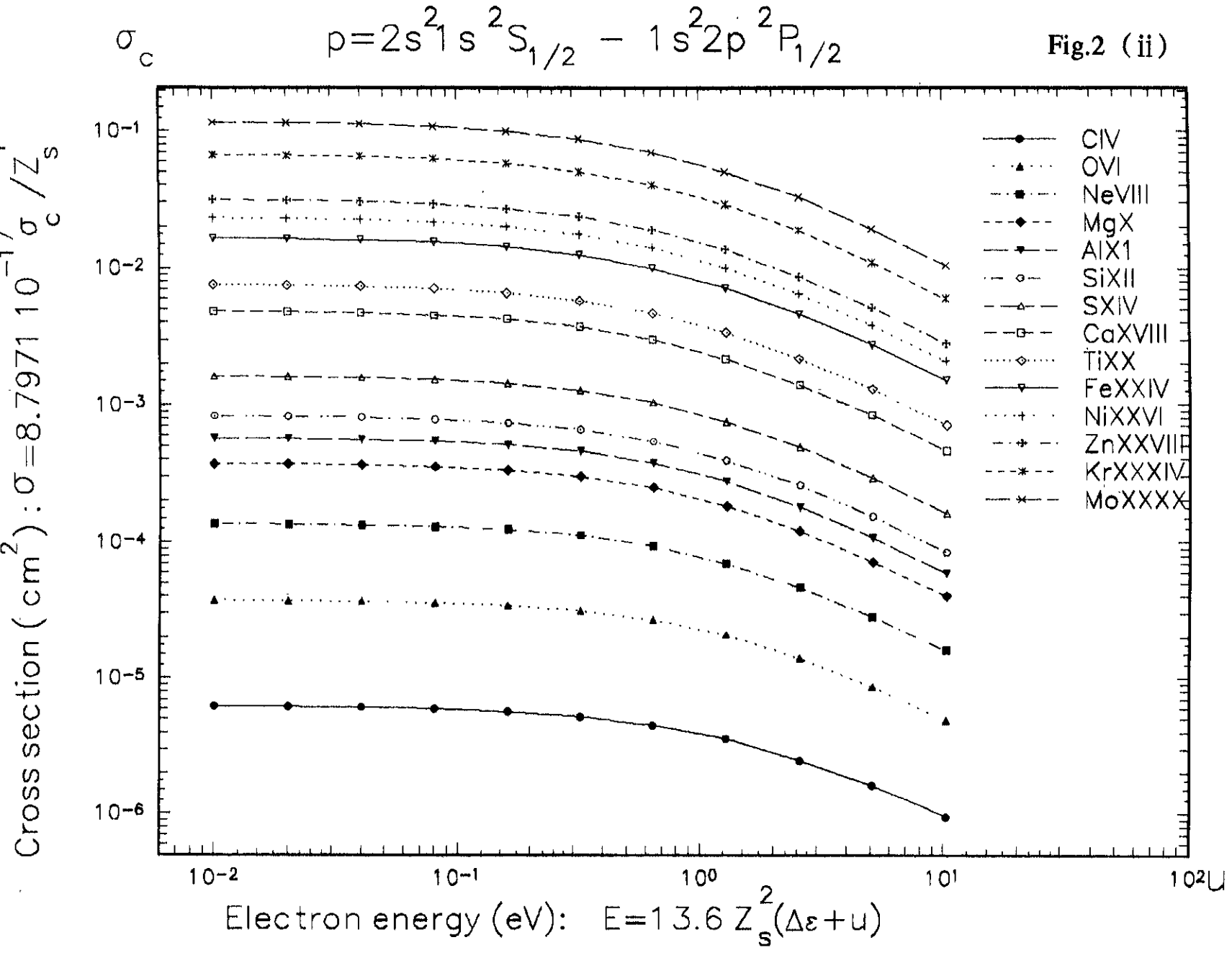

σc
p=2s²1s ²S1/2 − 1s²2p ²P1/2
Cross section (cm²): σ=8.7971 10⁻¹⁷ σc /Zs⁴
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻²
10⁻¹
10⁰
10¹
10²U
Electron energy (eV): E=13.6 Zs²(Δε+u)
ClV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

Fig.2 (ii)

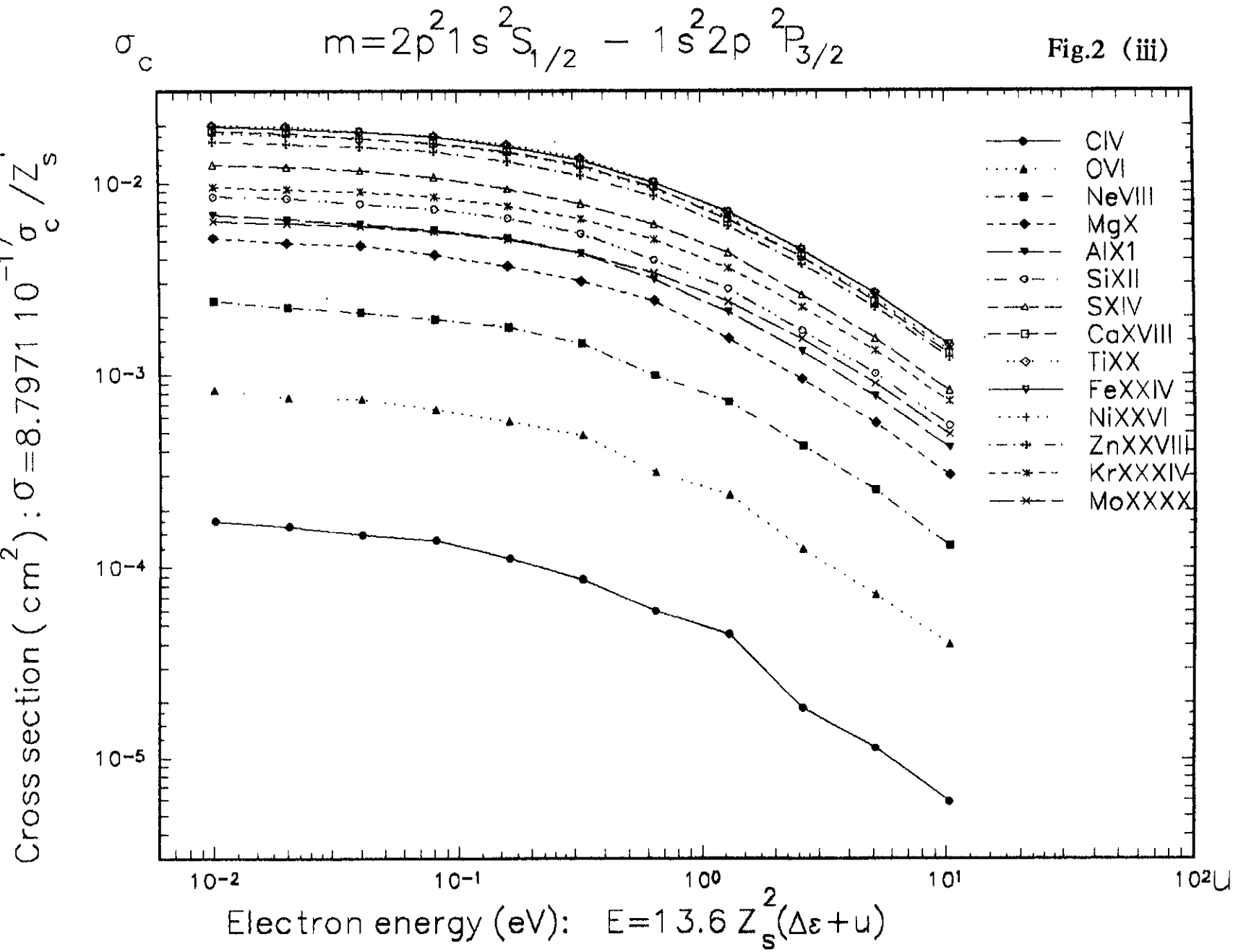

σc
m=2p²1s ²S1/2 – 1s²2p ²P3/2
Cross section (cm²): σ=8.7971 10⁻¹⁷ σc /Zs⁴
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻²
10⁻¹
10⁰
10¹
10²U
Electron energy (eV): E=13.6 Zs²(Δε+u)
CIV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

Fig.2 (iii)

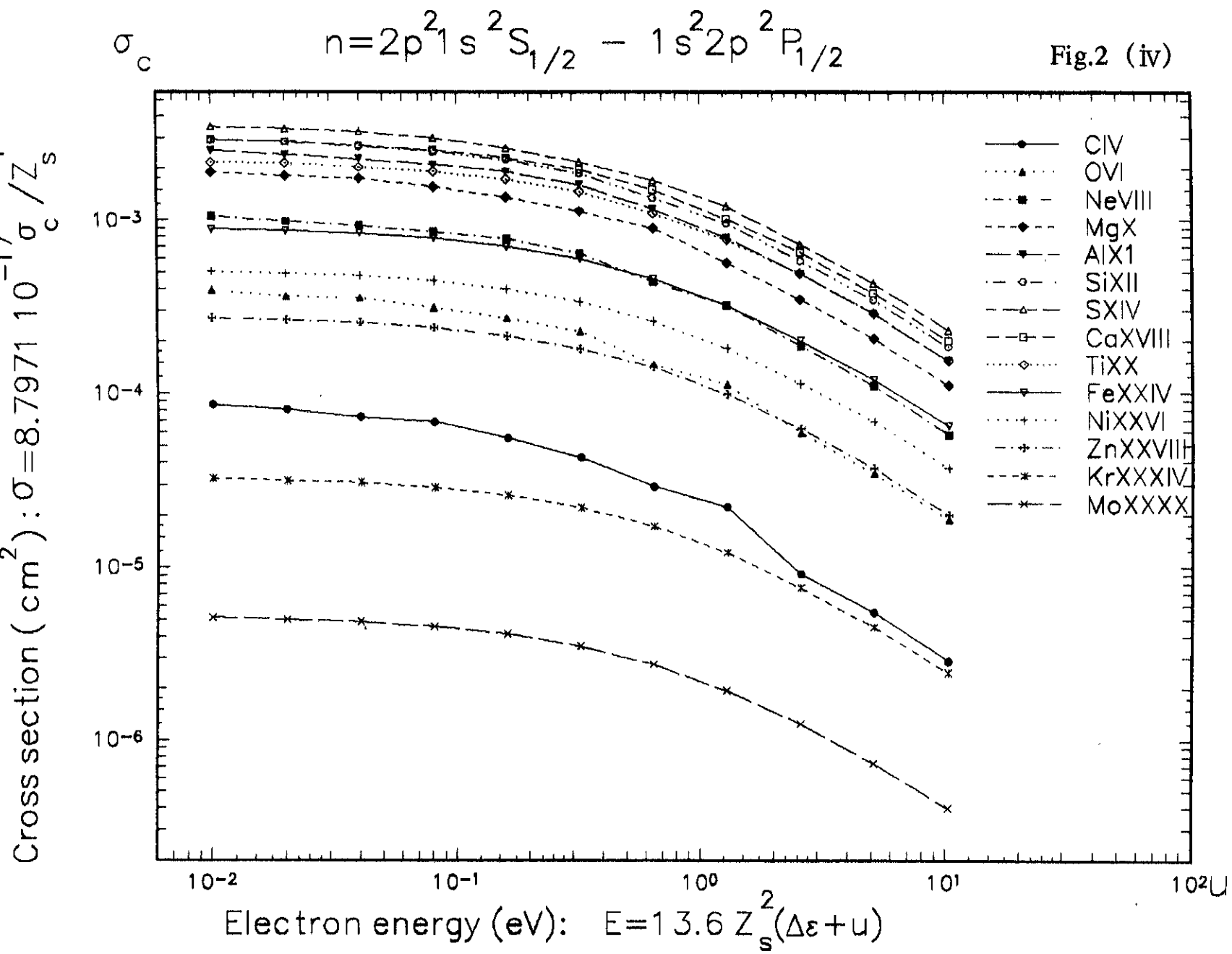

σc
n=2p²1s² ²S1/2 – 1s²2p² ²P1/2
Cross section (cm²): σ=8.7971 10⁻¹⁷ σc /Zs⁴
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻²
10⁻¹
10⁰
10¹
10²U
Electron energy (eV): E=13.6 Zs²(Δε+u)
CIV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

Fig.2 (iv)

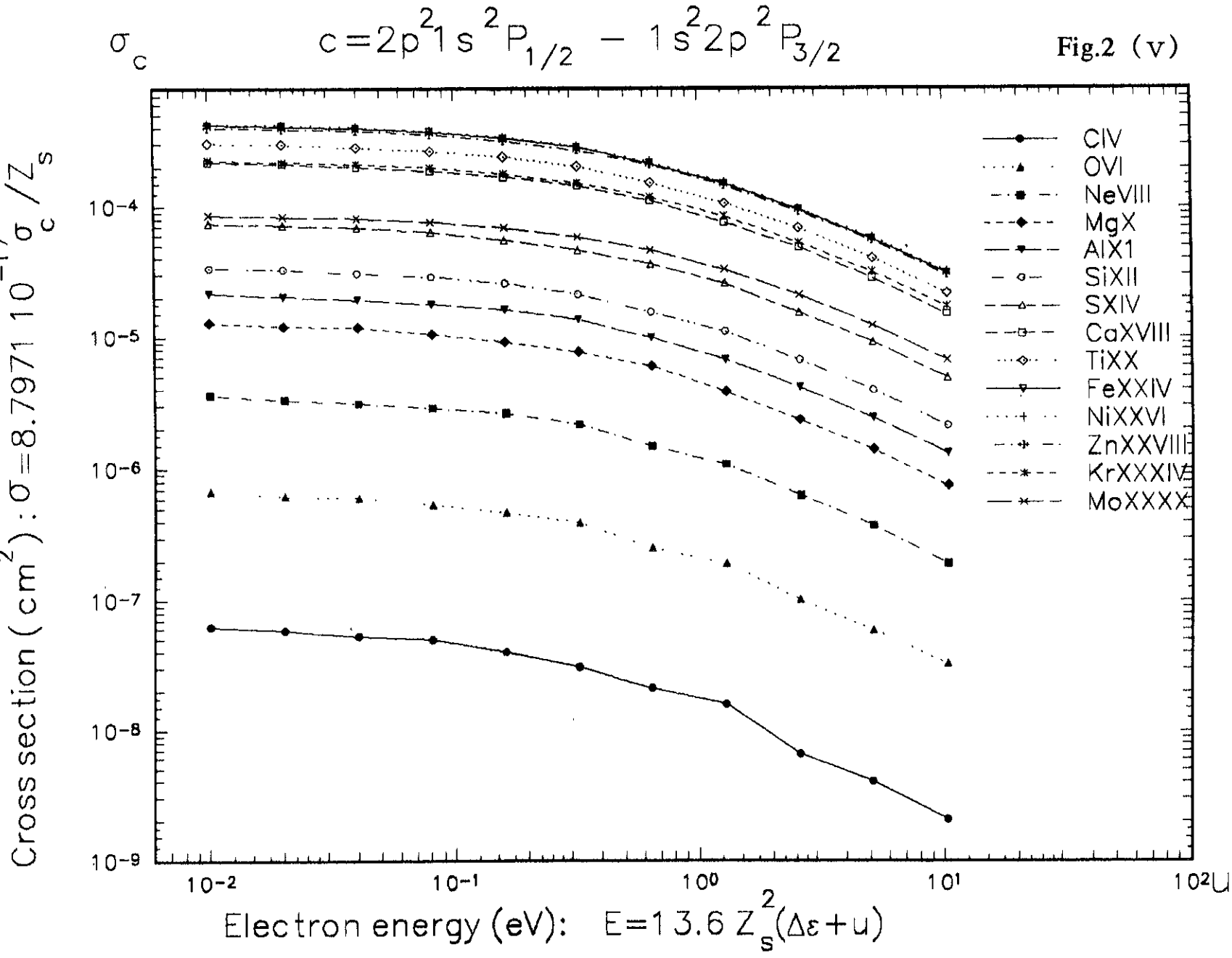
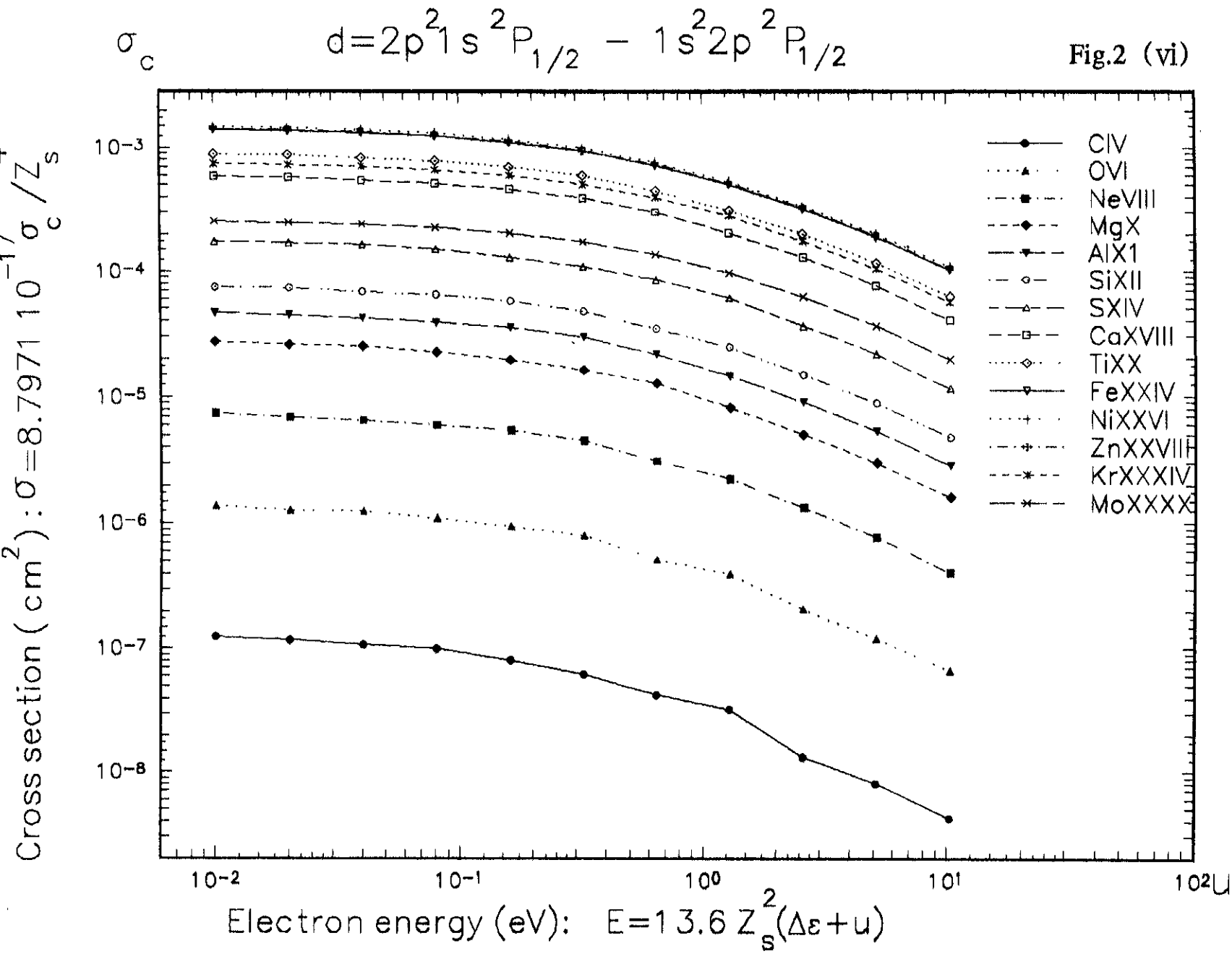

σc
c=2p²1s ²P1/2 − 1s²2p ²P3/2
Cross section (cm²): σ=8.7971 10⁻¹⁷ σc /Zs⁴
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻²
10⁻¹
10⁰
10¹
10²U
Electron energy (eV): E=13.6 Zs²(Δε+u)
ClV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

Fig.2 (v)


σc
d=2p²1s ²P1/2 − 1s²2p ²P1/2
Fig.2 (vi)
Cross section (cm²) : σ=8.7971 10⁻¹⁷ σc /Zs⁴
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻²
10⁻¹
10⁰
10¹
10²U
Electron energy (eV): E=13.6 Zs²(Δε+u)
ClV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

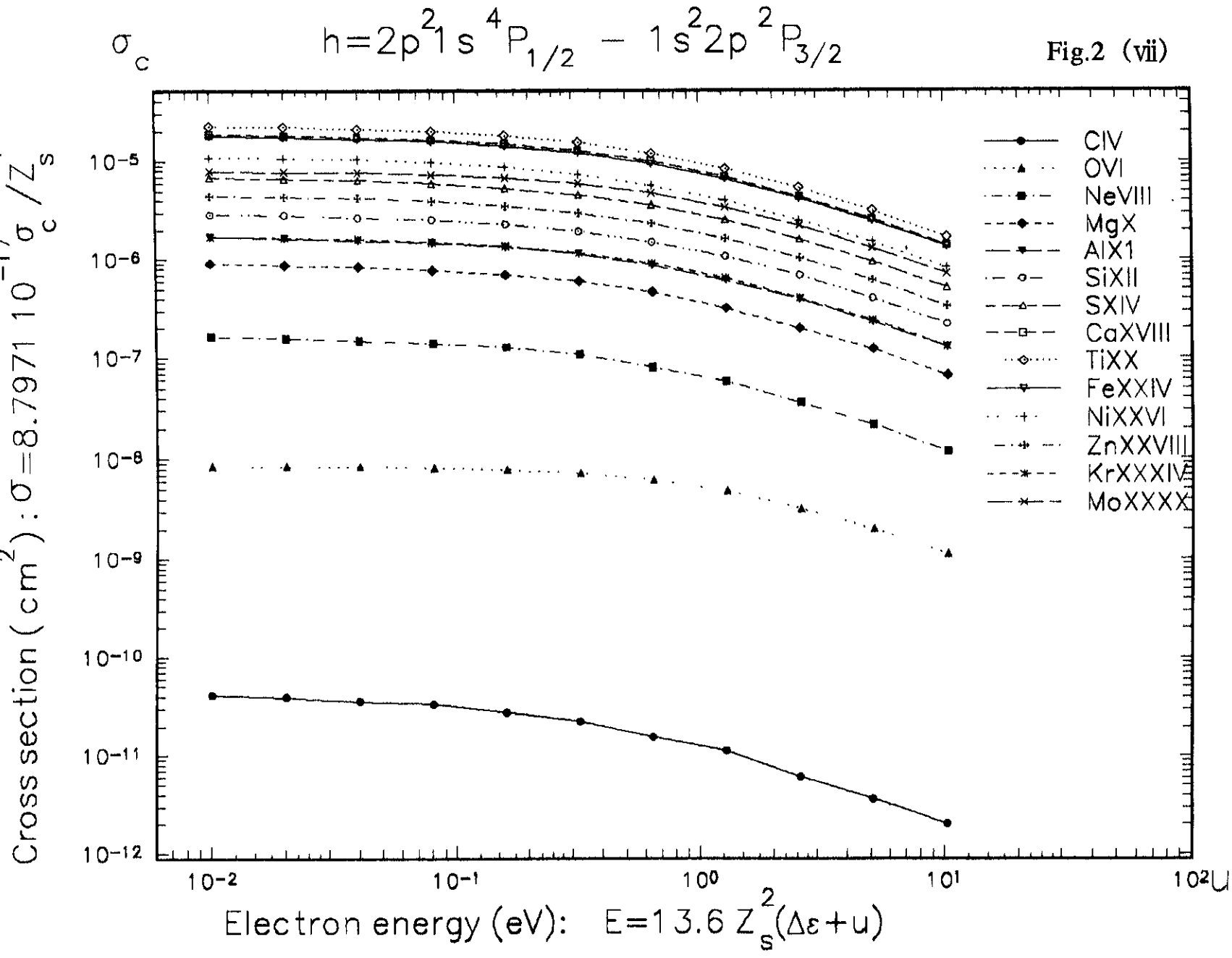

σc
h=2p²1s ⁴P1/2 − 1s²2p ²P3/2
Cross section (cm²): σ=8.7971 10⁻¹⁷ σc /Zs⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻²
10⁻¹
10⁰
10¹
10²U
Electron energy (eV): E=13.6 Zs²(Δε+u)
ClV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

Fig.2 (vii)

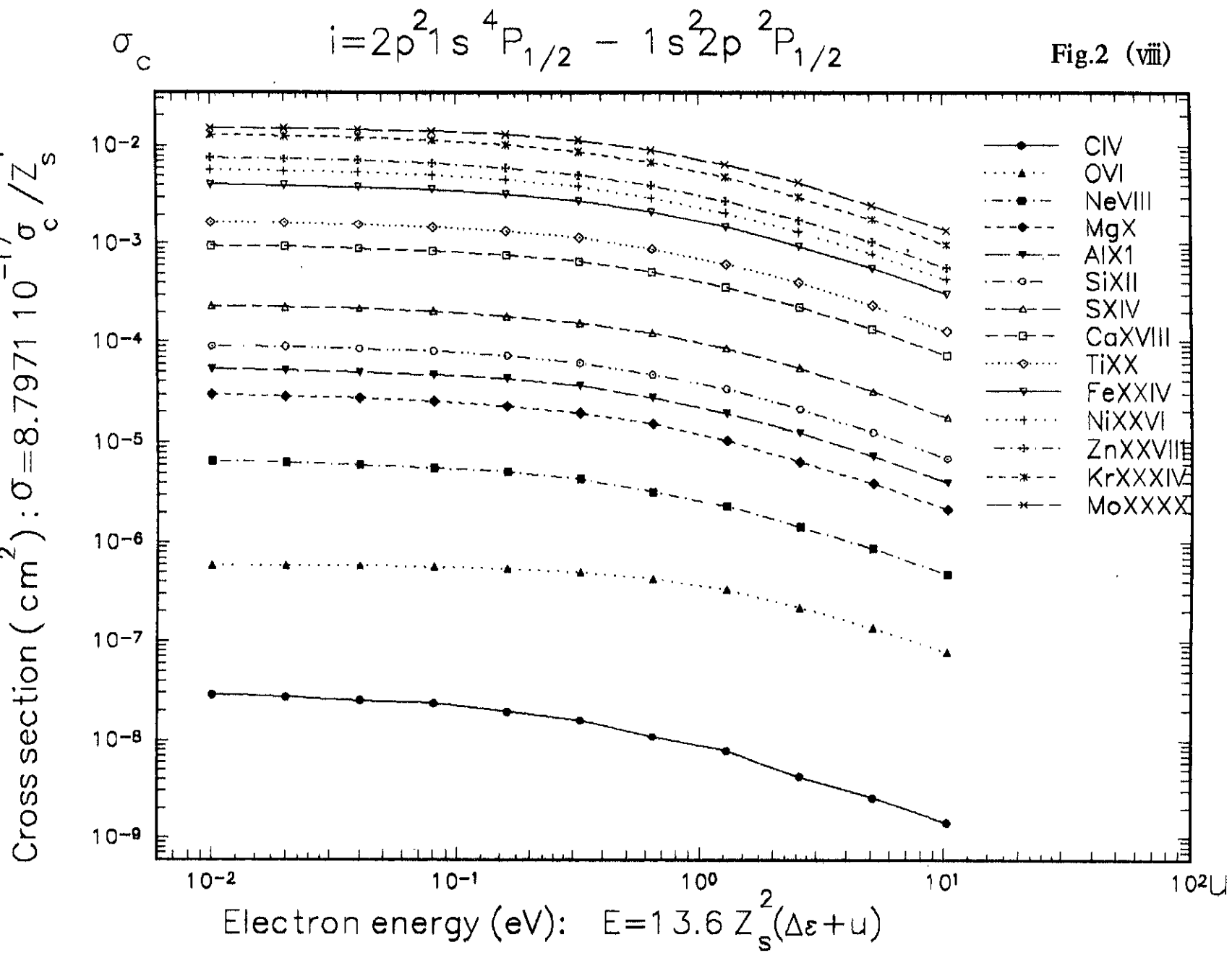
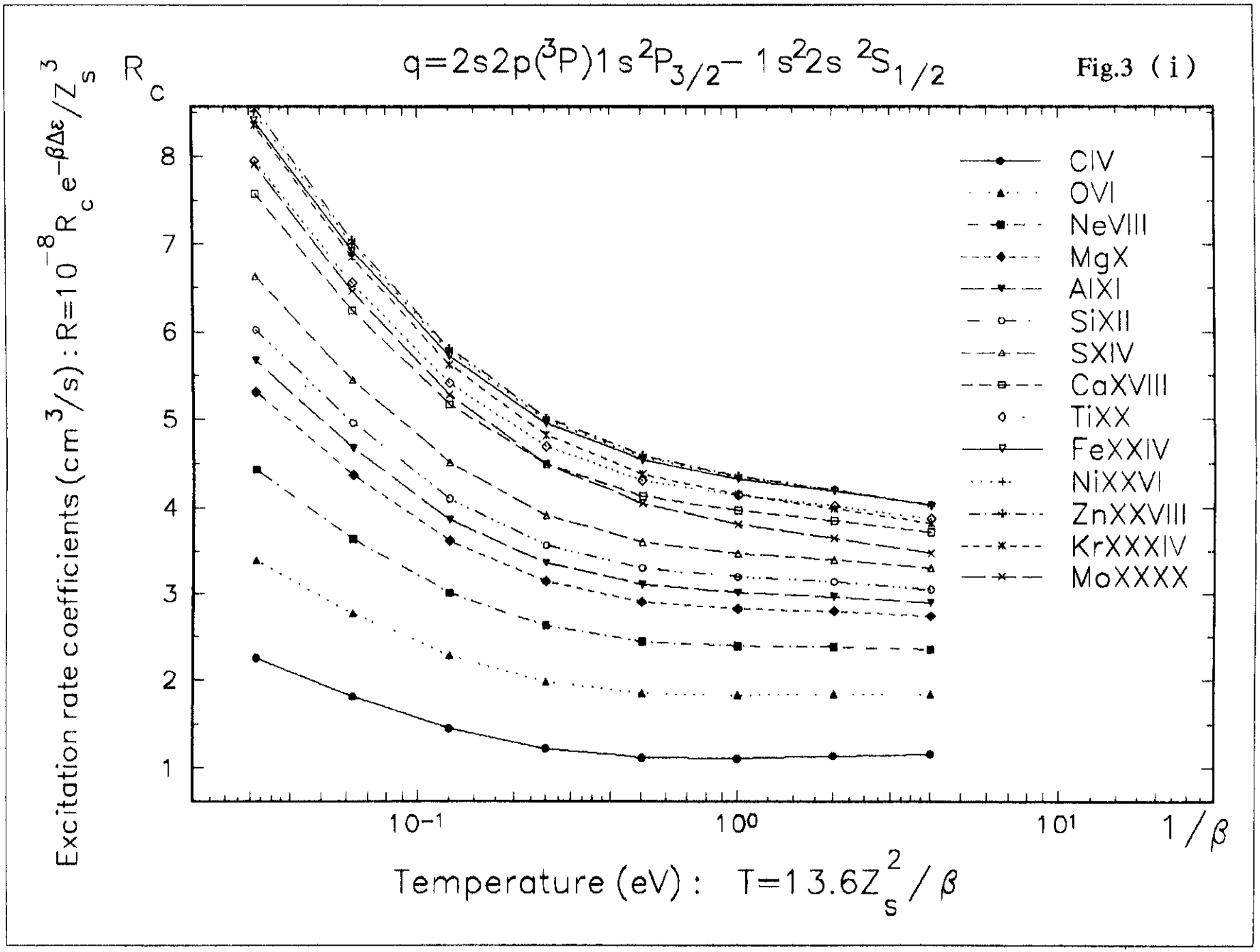
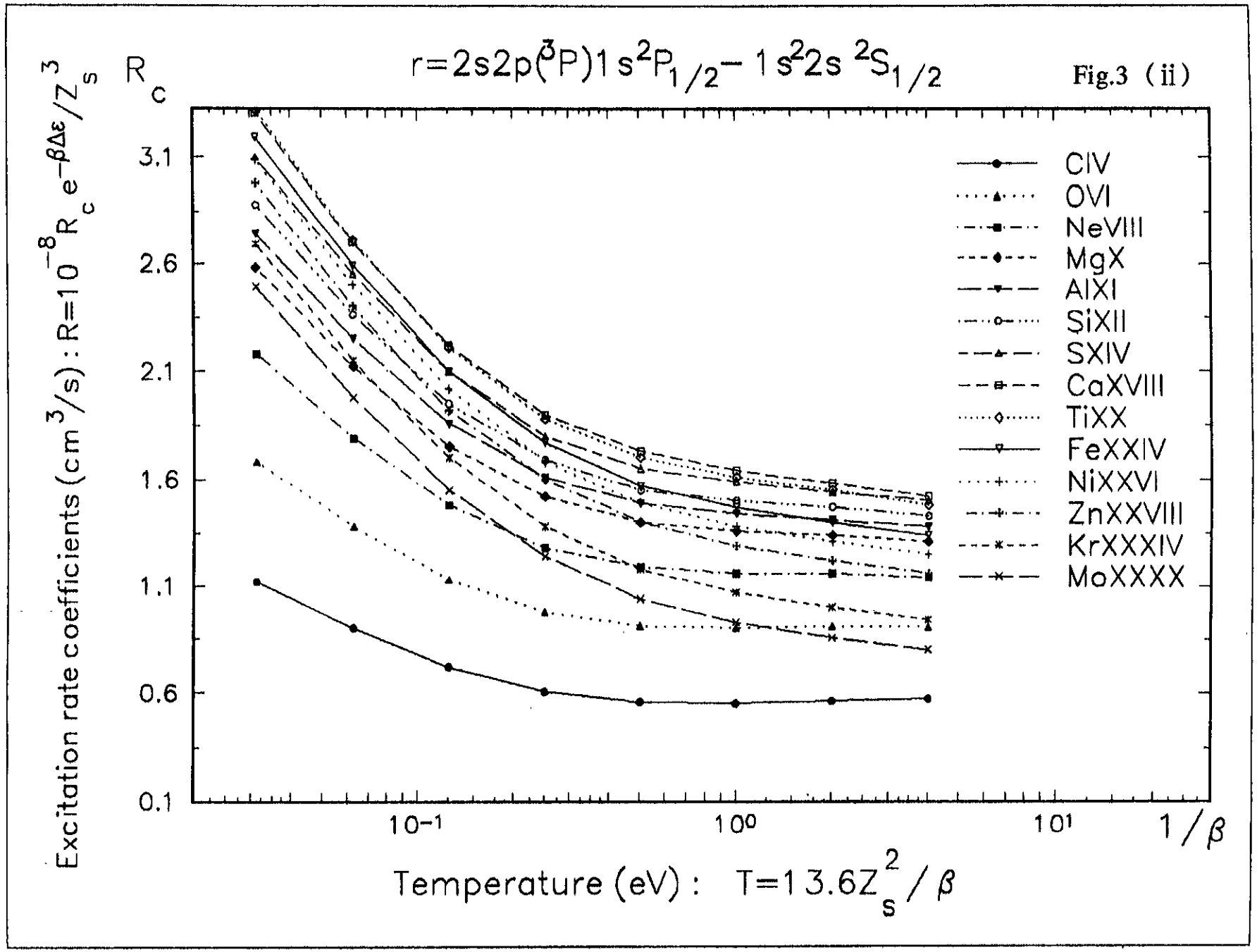
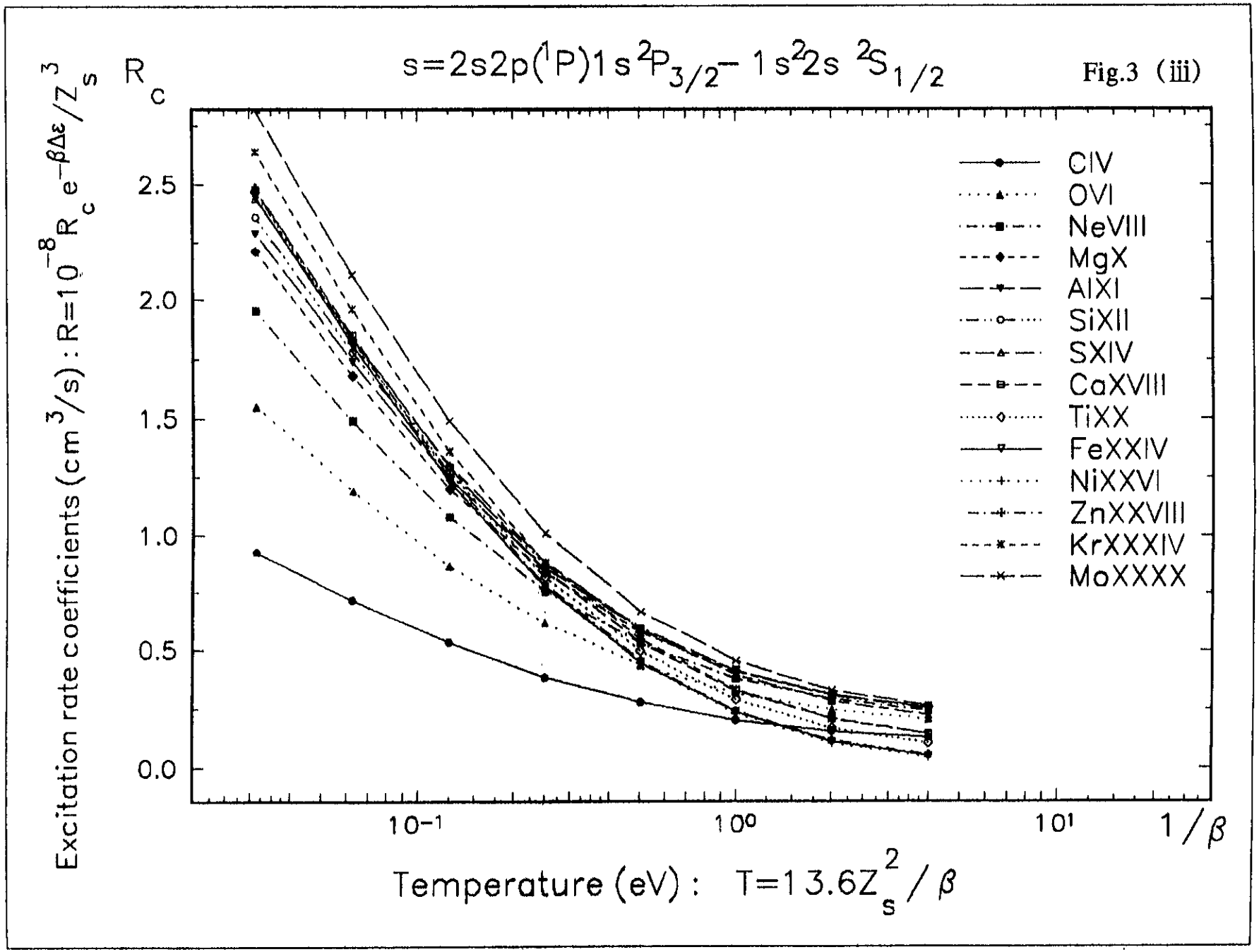
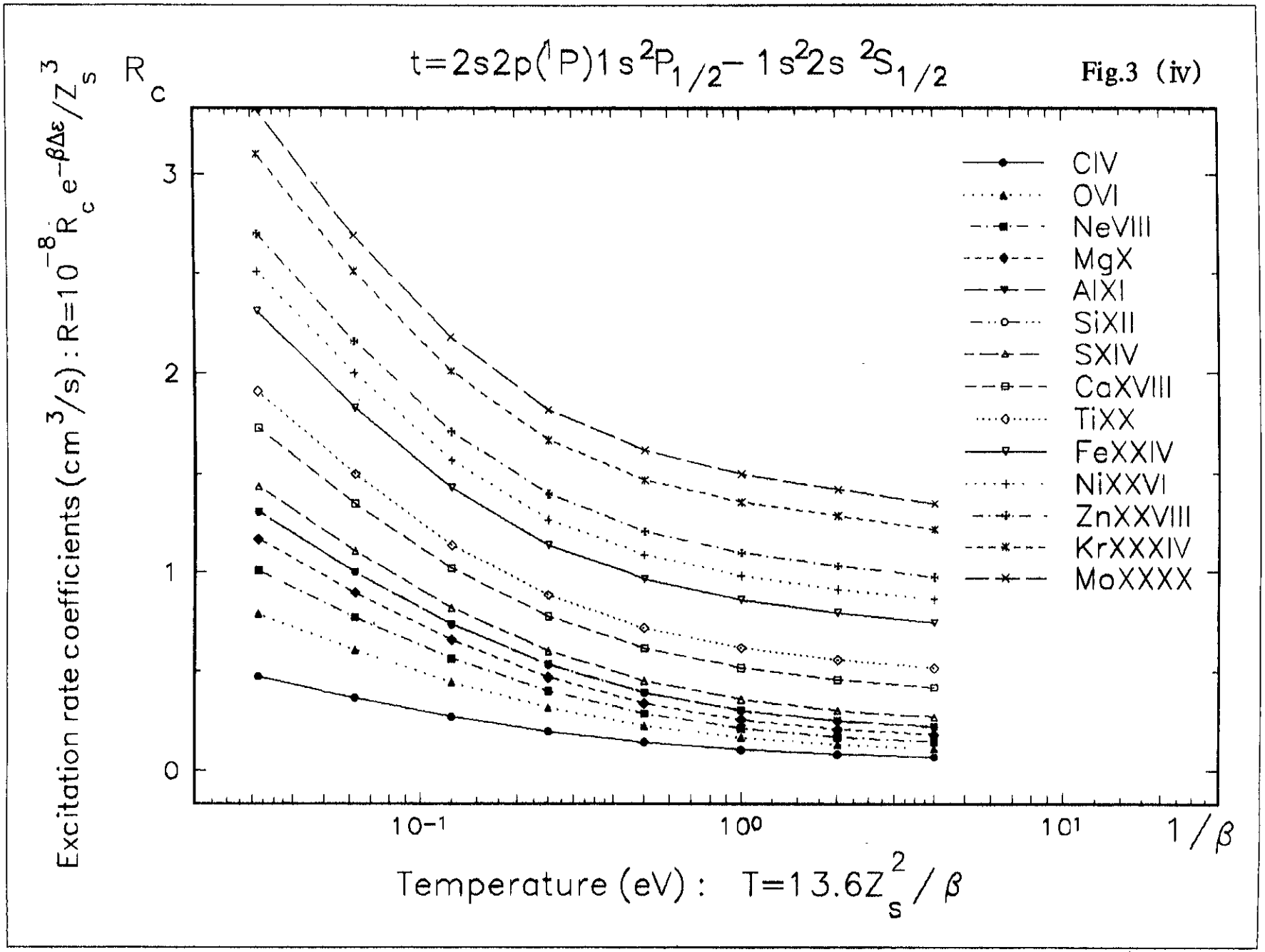

σc
i=2p²1s ⁴P1/2 – 1s²2p ²P1/2
Cross section (cm²): σ=8.7971 10⁻¹⁷ σc /Zs⁴
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻²
10⁻¹
10⁰
10¹
10²U
Electron energy (eV): E=13.6 Zs²(Δε+u)
CIV
OVI
NeVIII
MgX
AlX1
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

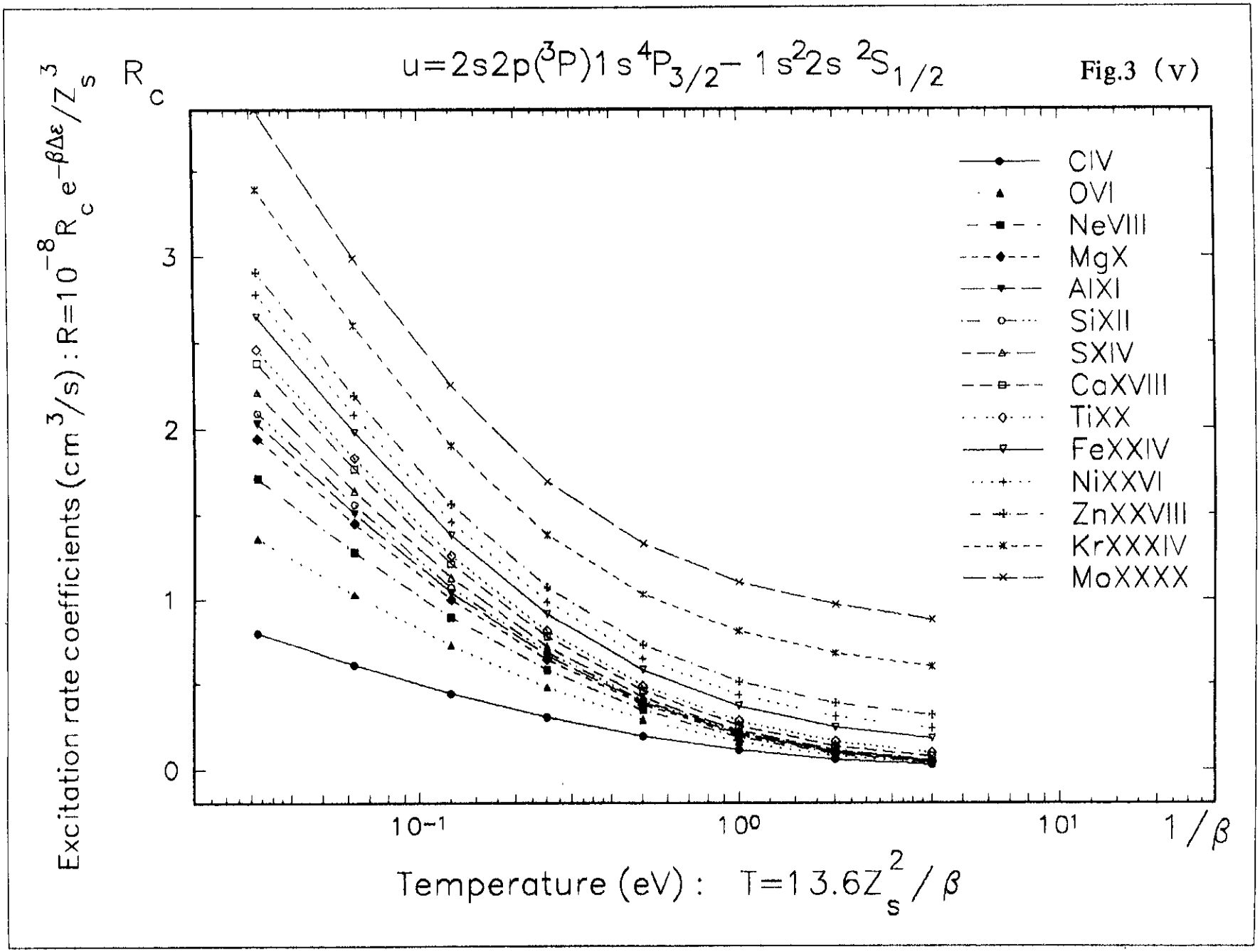
Fig.2 (viii)

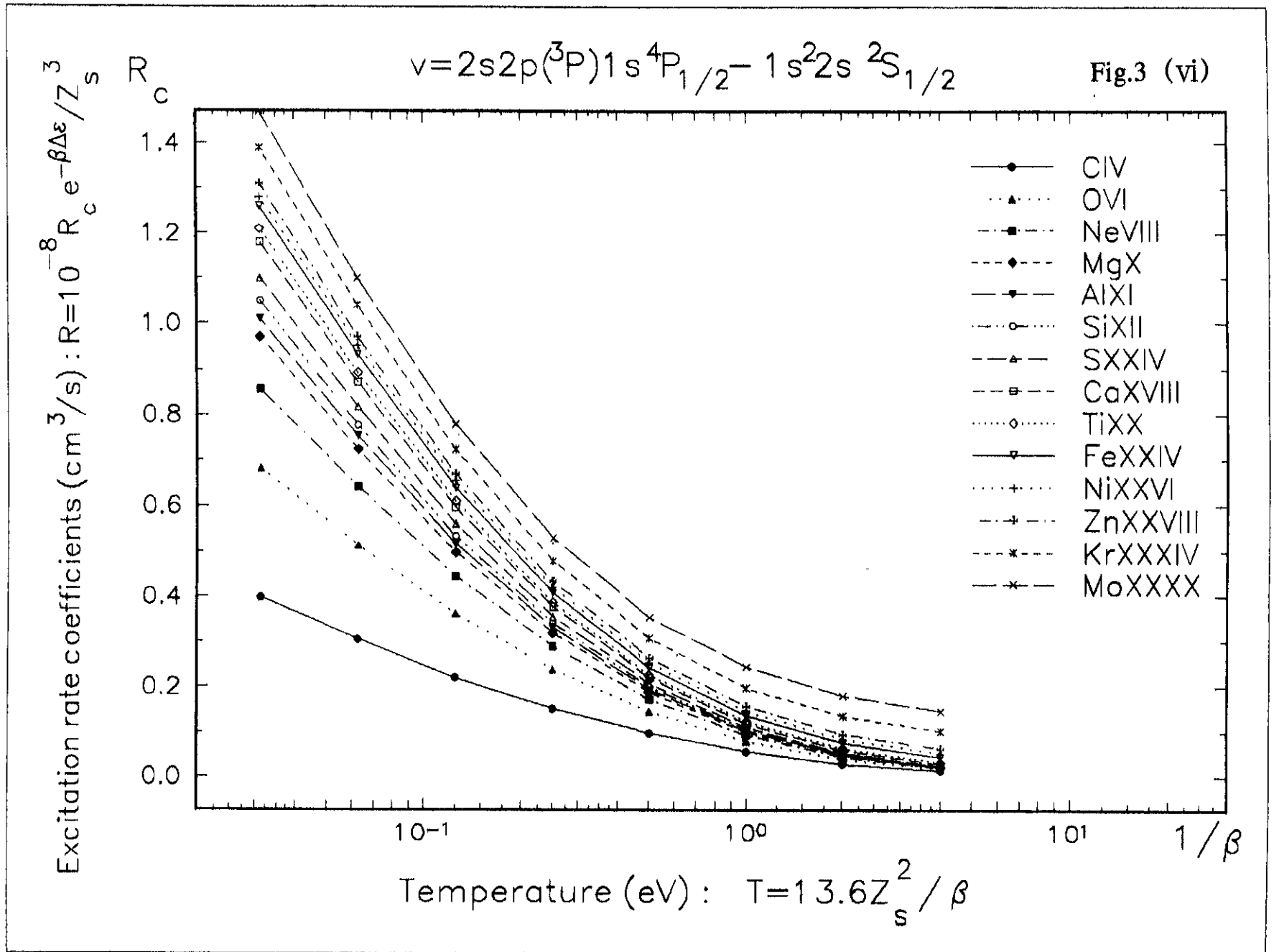

q=2s2p(3P)1s 2P3/2− 1s22s 2S1/2
Fig.3 (i)
Rc
Excitation rate coefficients (cm3/s) : R=10−8 Rc e−βΔε/Zs3
Temperature (eV) : T=13.6Zs2 / β
1/β
10−1
100
101
1
2
3
4
5
6
7
8
CIV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

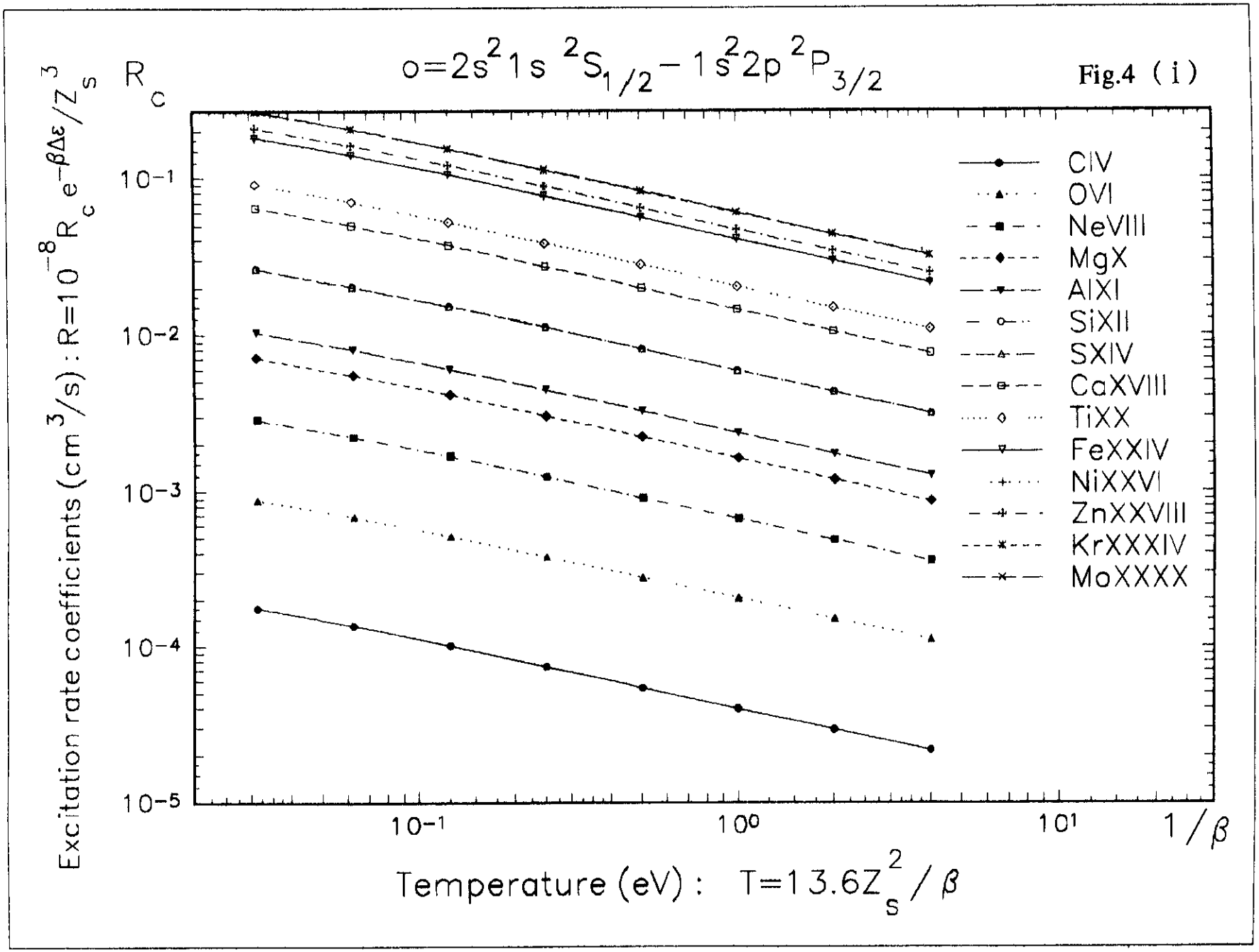

r=2s2p(3P)1s2P1/2– 1s22s 2S1/2
Fig.3 (ii)
Excitation rate coefficients (cm3/s) : R=10−8 Rc e−βΔε/Zs3
Rc
3.1
2.6
2.1
1.6
1.1
0.6
0.1
10−1
100
101
1/β
Temperature (eV) : T=13.6Zs2/β
ClV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

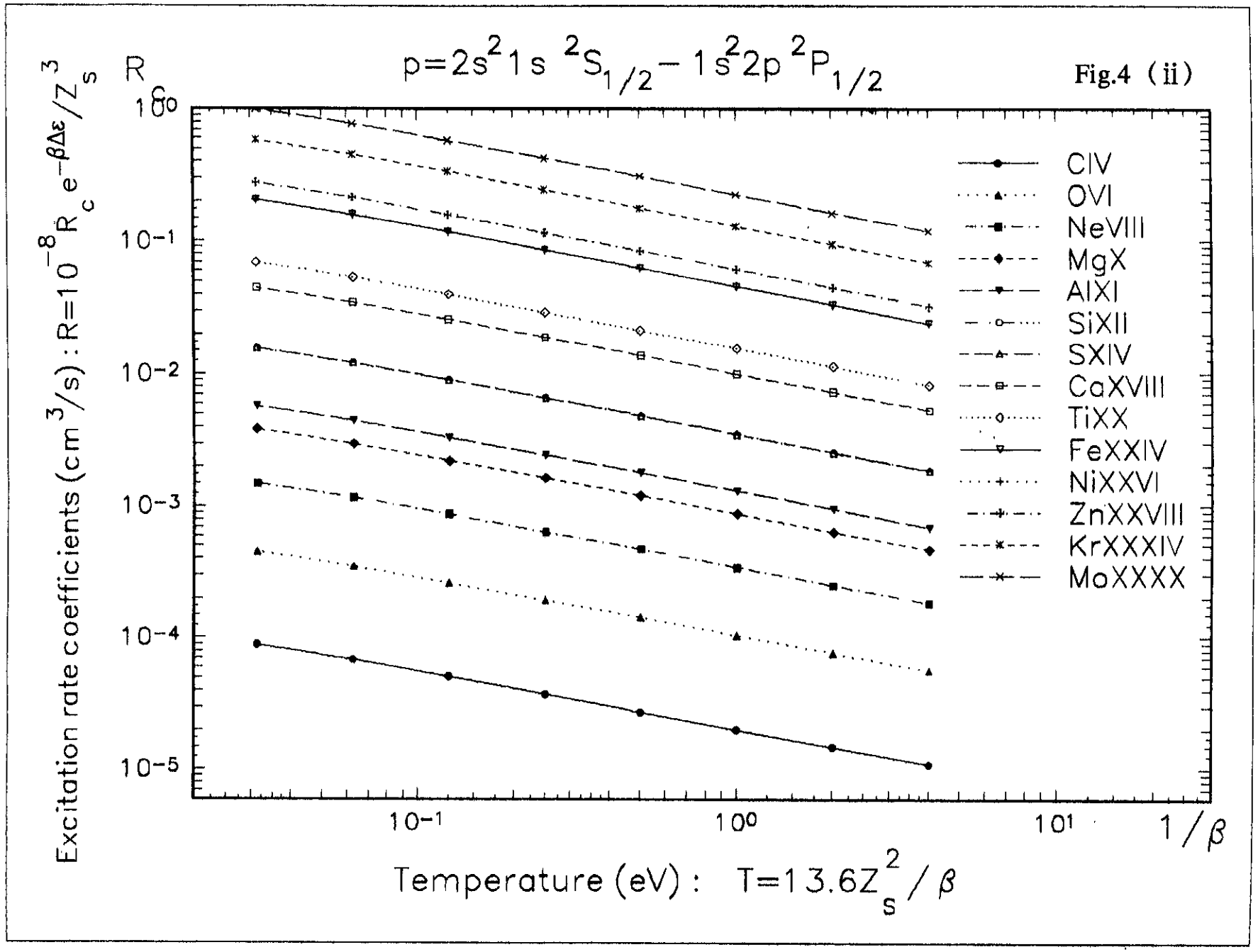

s=2s2p(1P)1s 2P3/2 – 1s22s 2S1/2
Fig.3 (iii)
Rc
Excitation rate coefficients (cm3/s) : R=10-8Rc e-βΔε/Zs3
2.5
2.0
1.5
1.0
0.5
0.0
10-1
100
101
1/β
Temperature (eV) : T=13.6Zs2/β
ClV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


t=2s2p(1P)1s 2P1/2 − 1s22s 2S1/2
Fig.3 (iv)
Excitation rate coefficients (cm3/s) : R=10−8 Rc e−βΔε/Zs3
Rc
3
2
1
0
10−1
100
101
1/β
Temperature (eV) : T=13.6Zs2/β
CIV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


u=2s2p(3P)1s 4P3/2– 1s22s 2S1/2
Fig.3 (v)
Rc
Excitation rate coefficients (cm3/s) : R=10-8 Rc e-βΔε/Zs3
0
1
2
3
10-1
100
101
1/β
Temperature (eV) : T=13.6Zs2/β
CIV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


v=2s2p(3P)1s 4P1/2– 1s22s 2S1/2
Fig.3 (vi)
Rc
Excitation rate coefficients (cm3/s) : R=10-8 Rc e-βΔε/Zs3
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
10-1
100
101
1/β
Temperature (eV) : T=13.6Zs2/β
CIV
OVI
NeVIII
MgX
AlXI
SiXII
SXXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


o=2s²1s ²S1/2 – 1s²2p ²P3/2
Fig.4 (i)
Rc
Excitation rate coefficients (cm³/s) : R=10⁻⁸ Rc e^(−βΔε/Zs³)
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻¹
10⁰
10¹
1/β
Temperature (eV) : T=13.6Zs² / β
ClV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


p=2s²1s ²S1/2 − 1s²2p ²P1/2
Fig.4 (ii)
Excitation rate coefficients (cm³/s) : R=10⁻⁸ Rc e^−βΔε/Zs³
R
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻¹
10⁰
10¹
1/β
Temperature (eV) : T=13.6Zs²/β
CIV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

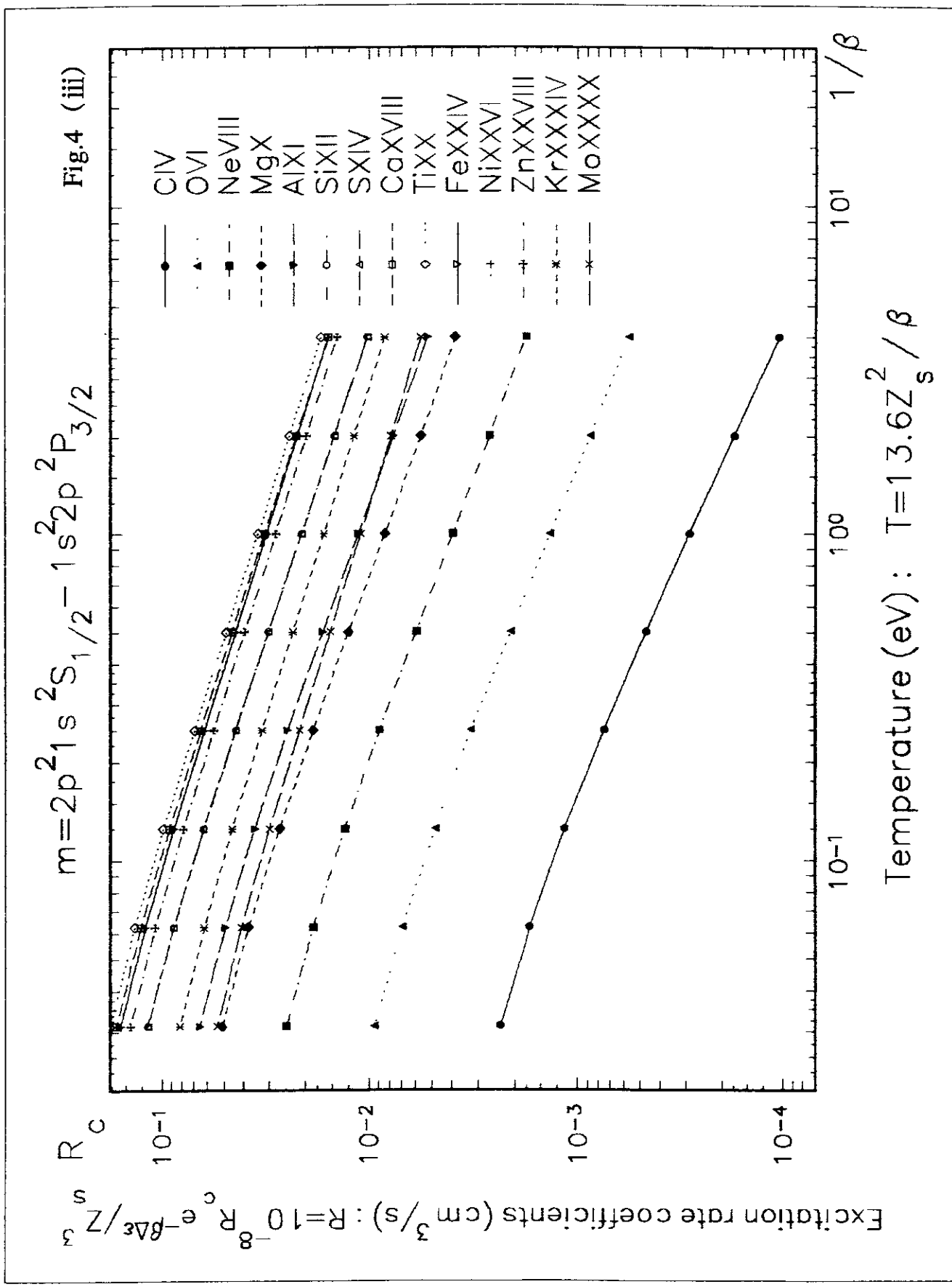
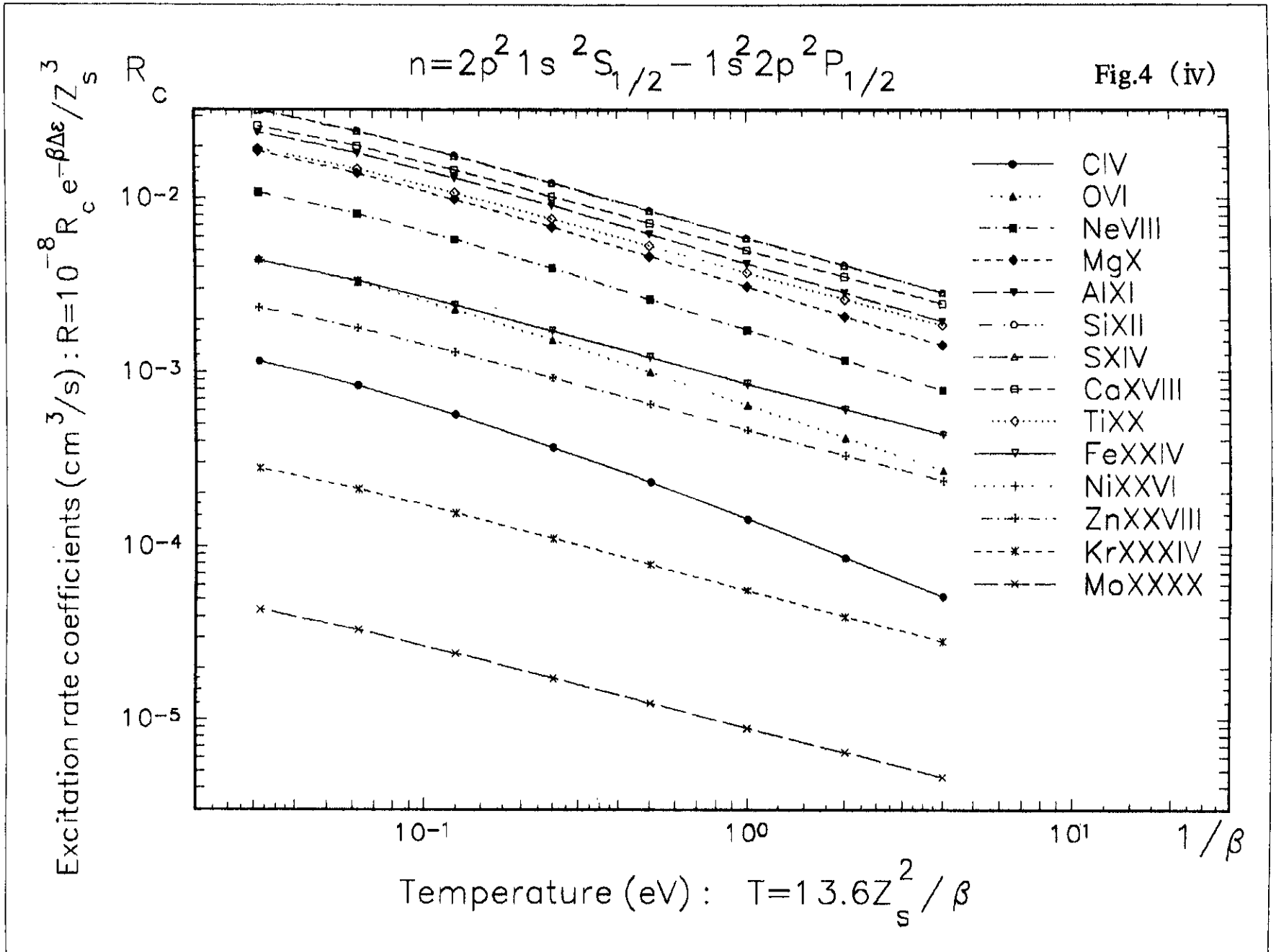


Fig.4 (iii)
m=2p²1s ²S1/2 − 1s²2p ²P3/2
Excitation rate coefficients (cm³/s) : R=10⁻⁸Rc e^−βΔε/Zs³
Rc
Temperature (eV) : T=13.6Zs²/β
1/β
ClV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


$n=2p^2\,1s\ ^2S_{1/2}-1s^2\,2p\ ^2P_{1/2}$
Fig.4 (iv)
R_c
Excitation rate coefficients (cm^3/s) : $R=10^{-8}R_c\,e^{-\beta\Delta\varepsilon}/Z_s^3$
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-1}
10^{0}
10^{1}
$1/\beta$
Temperature (eV) : $T=13.6Z_s^2/\beta$
CIV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

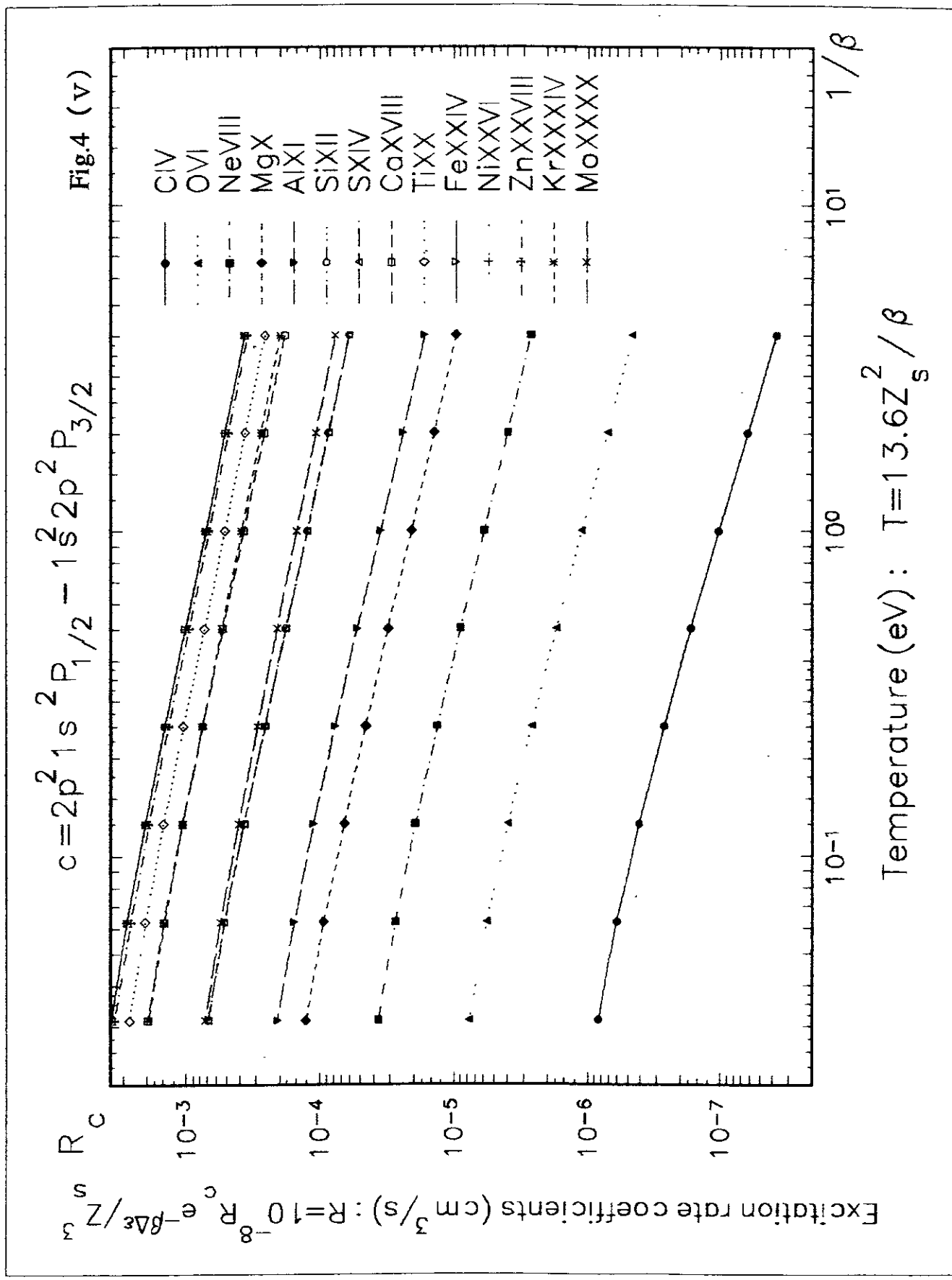


Fig.4 (v)
c=2p² 1s² ²P1/2 − 1s²2p² ²P3/2
ClV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX
Rc
10−3
10−4
10−5
10−6
10−7
10−1
10⁰
10¹
1/β
Temperature (eV): T=13.6Z²s/β
Excitation rate coefficients (cm³/s): R=10⁻⁸Rc e^−βΔε/Z³s

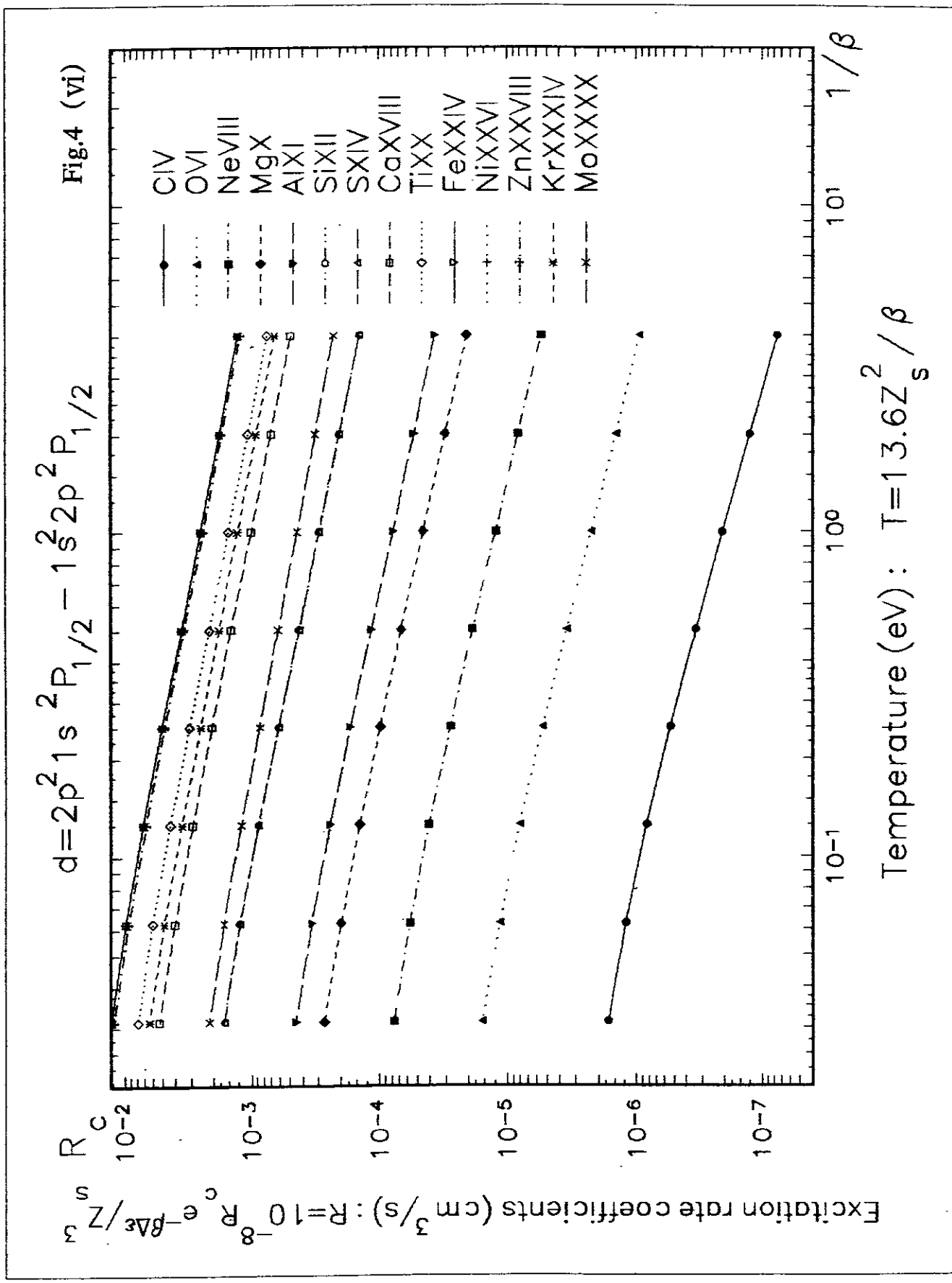
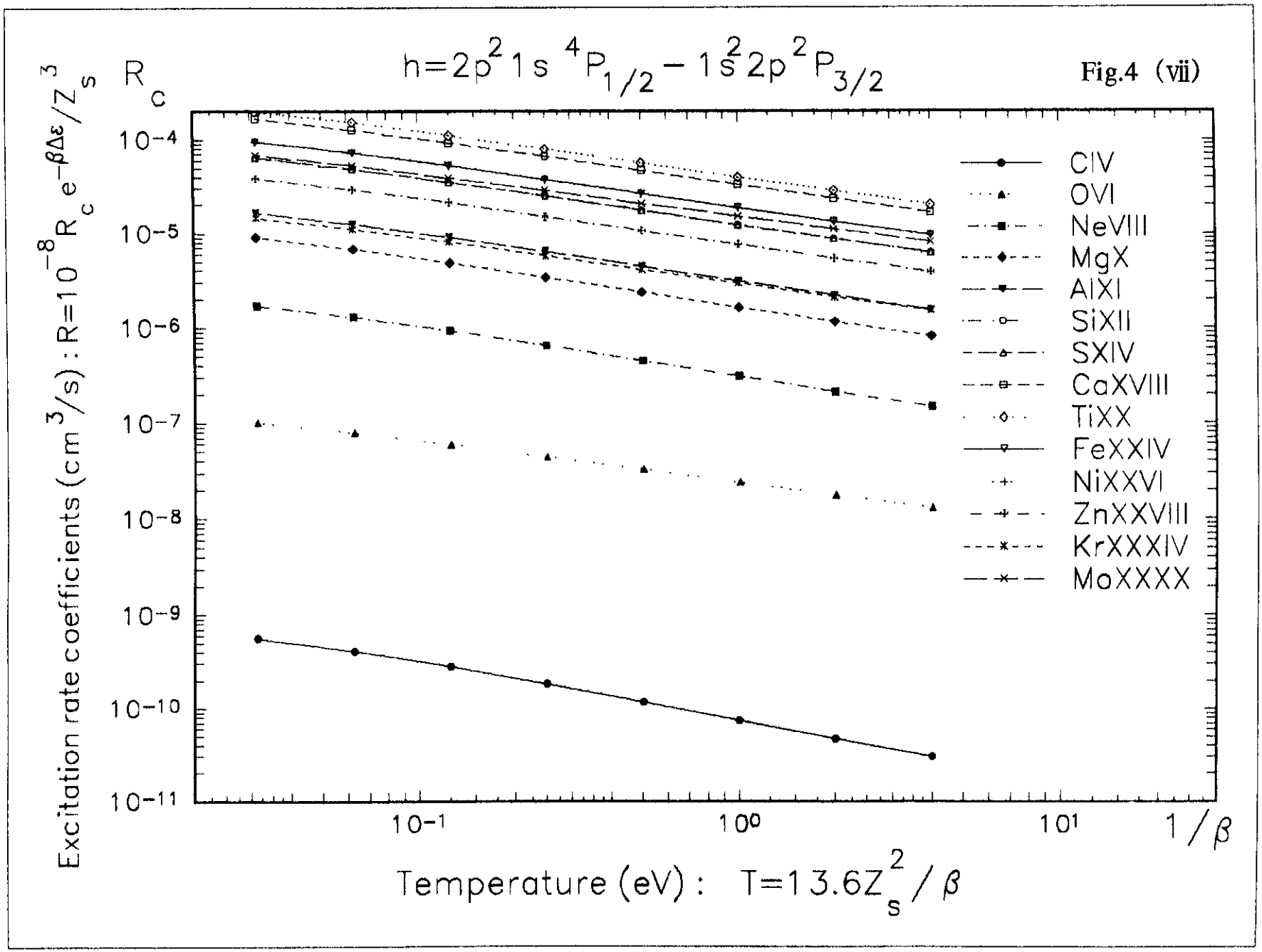
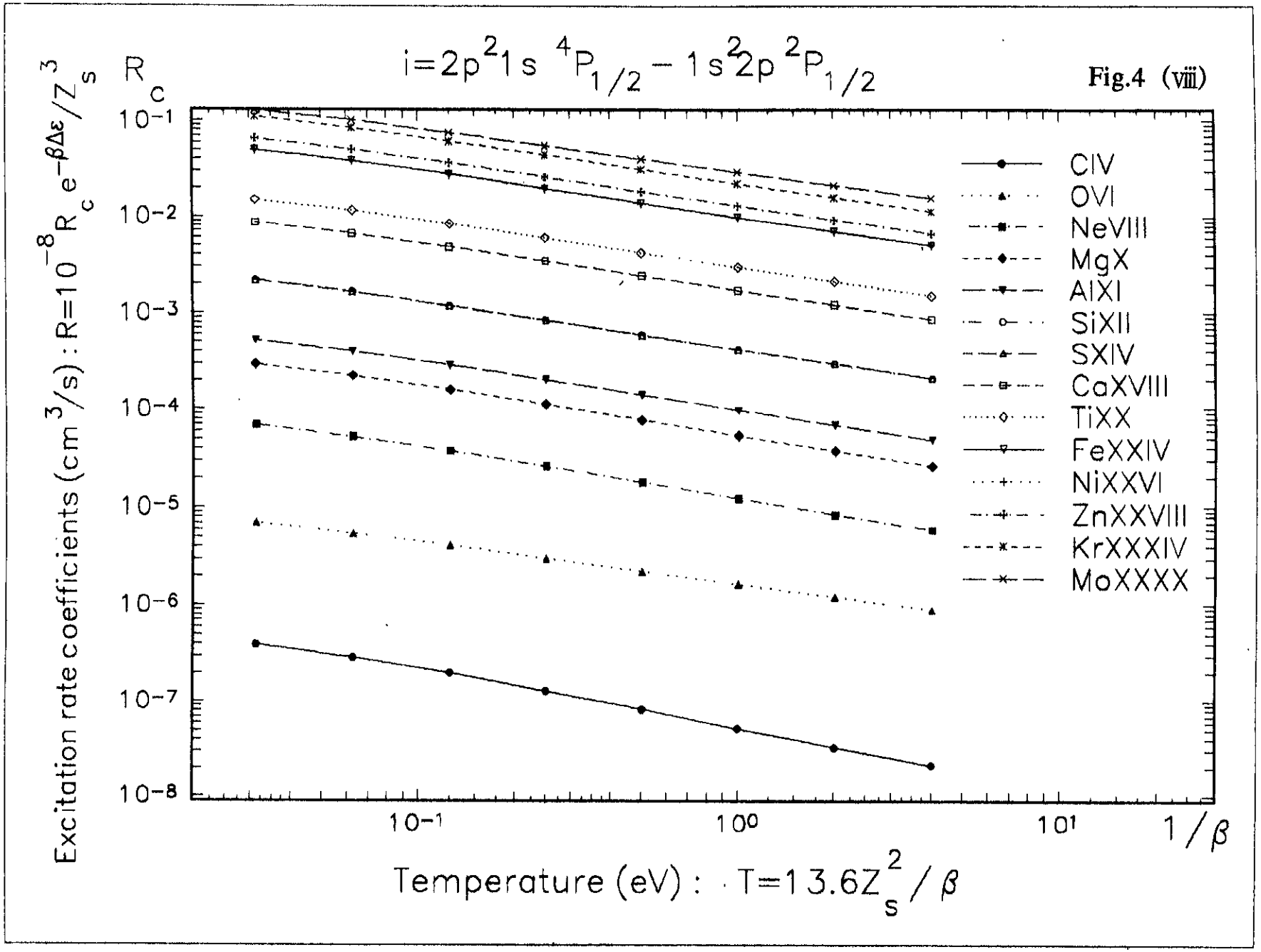


Fig.4 (vi)
d=2p²1s ²P1/2 − 1s²2p² P1/2
ClV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX
Excitation rate coefficients (cm³/s) : R=10⁻⁸ Rc e^(−βΔε)/Zs³
Rc
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻¹
10⁰
10¹
Temperature (eV) : T=13.6Zs²/β
1/β


h=2p² 1s ⁴P1/2 – 1s² 2p² P3/2
Fig.4 (vii)
Rc
Excitation rate coefficients (cm³/s) : R=10⁻⁸ Rc e^(−βΔε/Zs³)
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹
10⁰
10¹
1/β
Temperature (eV) : T=13.6Zs² / β
CIV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX


i=2p²1s ⁴P1/2 – 1s²2p ²P1/2
Fig.4 (viii)
Excitation rate coefficients (cm³/s) : R=10⁻⁸ Rc e^(−βΔε) / Zs³
Rc
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻¹
10⁰
10¹
1/β
Temperature (eV) : T=13.6Zs² / β
CIV
OVI
NeVIII
MgX
AlXI
SiXII
SXIV
CaXVIII
TiXX
FeXXIV
NiXXVI
ZnXXVIII
KrXXXIV
MoXXXX

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