# MEASUREMENT AND R-MATRIX CALCULATION OF SUPERELASTIC ELECTRON-SCATTERING CROSS-SECTIONS ON THE METASTABLE (3s3p) $^3P_{0,2}$ STATES IN Mg

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In the present paper the results experimental and theoretical investigations of superelastic scattering on the metastable 3s3p $^3P_{0,2}$ states of Mg represented. The experiments have been carried out on conditions of crossed electron and atomic beams. In experiment the part of integral cross section for super-elastic scattering in the range of scattering angles from 0 to ~0.5 rad was measured. Energy dependence of these cross sections for super-elastic scattering from metastable $3^3P_{0,2}$ states of Mg atom was obtained in the near-threshold region for energies from 0.15 up to 3 eV. The relative accuracy of obtained cross sections is estimated to be ~8%, the energy scale calibration errors are less then 0.1 eV. The resonance structure at electron energy ~0.45 eV was obtained. We used R-matrix method with pseudo-states in 35-state intermediate-coupling approximation for the calculation of electron-impact excitation cross sections in neutral Mg. The close-coupling expansion includes the 21 physical target states and 14 pseudo-states in the *LSJ* coupling scheme. The good agreement in the energy dependence of experimental and theoretical cross section at energies greater than 0.4 eV, but larger difference is observed in the near-threshold region was obtained. The origin of this difference is not clear, and further both theoretical and experimental investigations are desirable in this respect.

## Introduction

Accurate values of the cross sections for slow-electron collisions with neutral atomic magnesium, as well as with other alkaline-earth atoms, are of great practical importance in plasma physics (see, e.g., ref. [1, 2]). When the literature is surveyed for Mg and for Ca, Sr, and Ba, it is immediately apparent that fewer papers (both theoretical and experimental) have been published for Mg. Evidently this neglect of Mg is associated with capricious features of the Mg atom which are not easily modeled, in spite of its seeming simplicity.

In view of the long lifetimes of the metastable states (in some cases above $10^{-5}$ s) and also the large expected values of the corresponding cross-sections (typically $10^{-15}$ cm$^2$), one expects these processes to play a fundamental role in a variety of plasma and laser devices.

Electron-impact excitation of Mg is also of considerable interest from the theoretical standpoint. A primary reason is that Mg is a relatively simple atom, in which both the ground state and the excited states can be well described within the *LS* or *LSJ* coupling formalism. On the other hand, Mg as a target in electron-impact processes shows significantly different behavior when compared to He, a much-studied target in electronic collisions. While the ground state of Mg is also a closed-shell $^1S$ state, it shows strong electron correlation effects, and the low-lying optically allowed transitions are strongly coupled to each other. Therefore it is interesting to investigate the influence of these features on the various observable that can be extracted from electron scattering experiments.

The detailed conclusion experimental and theoretical investigation integral cross section of $e$ + Mg scattering were in here work [3] represent. In [3] carried out the results of 19-state R-matrix calculations with pseudo-states (RMPS) – (19CC) for $e$ + Mg scattering. The target states are represented by configuration-interaction (CI) wave functions and include the 13 low-lying bound states of Mg with principal quantum numbers $n \le 4$, as well as the $(4s5s)\ ^{1,3}S$ states.

In particular, we have received the good consent with experimental results Shpenik *et al.* [4]. With their higher energy resolution (half width 0.1 eV), they observed several sharp structures in the excitation functions at impact energies below 10 eV, which they attribute to the decay of short-lived autodetaching states of the negative $Mg^-$ ion. The good consent with recent experimental efforts in measuring excitation cross sections from the metastable levels of Mg atom [5] also was obtained. Absolute values for the excitation cross sections have been obtained for 5 transitions from the $3^3P_{0,2}$ metastable state of Mg [5].

The measurements and calculations presented here are intended to complement and extend the experimental research and theoretical studies for investigation electron-impact deexcitation of the $(3s3p)\ ^3P_{0,1,2}$ states in Mg.

With the interaction of the slow incident electron and atom in the excited state the following process is possible: the atom passes from this excited state into the energetically lower excited one, and the surplus of liberated energy at this non-radiative transfer is imparted to the electron. As a result the electron kinetic energy is increased. Such a process belongs to the inelastic collisions of the second kind. In modern scientific literature this process was given the term "superelastic electron scattering on the excited atoms".

Schematically the superelastic process can be described by the reaction:

$$e^-(E) + A_j^* \rightarrow \tilde{e}^-(E + \Delta E) + A_i^*, \qquad (1)$$

$$\Delta E = E(A_j^*) - E(A_i^*), \qquad (2)$$

where $e^-(E)$ is the slow incident electron with the energy $E$; $A_j^*$ is the atom in the excited $j$-th state with the energy $E(A_j^*)$; $A_i^*$ is the atom in the excited $i$-th state with the energy $E(A_i^*)$ and the $E(A_j^*) > E(A_i^*)$; $\tilde{e}^-(E + \Delta E)$ is the high-speed super-elastically scattered electron with the energy $(E + \Delta E)$.

In works [6, 7] the experiments of the measurement of the cross section of superelastic electron scattering from magnesium and establishing the mechanisms of their transferring were carried out. The energy dependences of the differential cross section of superelastic electron scattering by the metastable $3\ ^3P_{0,2}$ states of magnesium atom were obtained for the first time.

In this connection it is clear that accurate calculations of total and differential cross sections, and the detailed analysis of excitation functions for Mg, are a significant undertaking with fundamental scientific interest as well as value for practical applications.

In this paper we present the results of experiments of the measurement of the cross

section of superelastic electron scattering from magnesium and 35-state RMPS calculations (35CC) for $e + Mg$ scattering. The target states are represented by configuration-interaction (CI) wave functions and include the 21 low-lying bound states of Mg with principal quantum numbers $n \leq 4$.

The present work is a continuation and development of a series of works devoted to measurements and calculations of electron scattering by alkaline-earth atoms and ions in the near-threshold-energy region, from both the ground state and the metastable states [2, 3, 5-11]. These investigations are directed toward the analysis and interpretation of measurements of cross sections undertaken at Uzhhorod National University.

**Experiment**

The given article describes the essence of our experiments and the obtained results of superelastic electron scattering by metastable magnesium atoms.

The experiments have been carried out on the original experimental setup in the conditions of the crossed electron and atomic beams. The electron spectrometer has been used. It was composed of the source of monoenergetic beam of electrons of regulated energies, the analyzer of scattered electrons energies and the system of the registration. The scheme of the experiment is given in Figure 1.

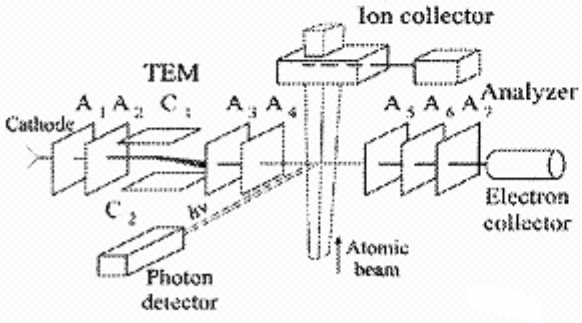


Figure 1. The scheme of the experiment.

A trochoidal electron monochromator (TEM) was used as the electron beam source. This monochromator was created the basis of works of Stamatovic and Schulz [12] as well as Shpenik and his collaborators [13]. In monochromators of this type selection of electrons according to the energies is carried out in the interperpendicular electric and magnetic fields. The intensity of electric field and the induction of the magnetic field were $\sim 1.2 \cdot 10^2$ V/m and $\sim 1.5 \cdot 10^{-2}$ Tl, respectively. The nonuniformity of the TEM beam was $\sim 0.1$ eV (at the half maximum) for energies 2 eV and current $\approx 5 \cdot 10^{-8}$ A.

The analyzer of the scattered electron energies is of the retarding type. It is the system of three flat electrodes with round diaphragms. The potentials of the edge electrodes are identical and equivalent to the accelerating potential. A retarding potential is applied to the middle electrode. The relative distribution of the analyzer at the energy of 2 eV is equivalent to $5 \cdot 10^{-2}$.

The system for registration of electrons, having passed the analyzer, consists of an electron collector, an electrometric amplifier, and a X-Y recorder.

The plan of experiment both research techniques envisioned detection and recording of ions and radiation, which one arose in an interaction range (see Fig. 1).

The discharge of excitation technique was used to obtain the beams of metastable magnesium atoms. It means that the beam of Mg atoms being obtained by thermal effusion in the ground state passes through the discharge space, where atoms transit into excited states under the conditions of discharge electrons. The method of obtaining of metastable atom beam is described in [14].

In the process of the performed investigation the parameters of the atomic beam in the region of its interaction with the beam of electrons were the following: the concentration of metastable atoms of Mg in $3s3p\ ^3P_{0,2}$ state was $\approx 6 \cdot 10^9$ cm$^{-3}$, concentration of Mg atoms in the ground state $3s^2\ ^1S_0$ is $\approx 5 \cdot 10^{10}$ cm$^{-3}$, the angle of divergence of the atomic beam was $\sim 8.7 \cdot 10^{-2}$ rad. The research was carried out in the vacuum $\sim 6.5 \cdot 10^{-6}$ Pa.

## Theory

*The total wave function used in the R-matrix method [15] to describe the collision in the inner region,* $r < a$, *where exchange between the projectile and the target electrons is negligible, can be written as an expansion in terms of a set of basis functions*

$$\Psi_k(\mathbf{r}_1,\ldots,\mathbf{r}_N,\mathbf{r}) = A\sum_{ij} a_{ijk}\Phi_i(\mathbf{r}_1,\ldots,\mathbf{r}_N,\hat{\mathbf{r}},\sigma)\frac{1}{r}u_j(r) + \sum_j b_{jk}\phi_j(\mathbf{r}_1,\ldots,\mathbf{r}_N,\mathbf{r}). \quad (3)$$

*Here the* $\Phi_i$ *are channel functions formed from all the target states (physical and pseudo) included in the expansion, the* $u_j(r)$ *are continuum orbitals that describe the motion of the scattering electron, and the* $\phi_i$ *are* $(N+1)$*-electron bound configurations, constructed from the target configurations plus another target orbital. The second sum in (1) includes at least those configurations that are required to compensate for orthogonality constraints imposed on the radial solutions* $u_j(r)$. *Finally,* $\hat{\mathbf{r}}$ *and* $\sigma$ *denote the angular and spin coordinates of the projectile, and the operator* $A$ *ensures full anti-symmetrization of the wave functions. The coefficients* $a_{ijk}$ *and* $b_{jk}$ *were found by diagonalizing the* $(N+1)$*-electron Hamiltonian inside the* R*-matrix box, of radius* a. *To perform the present scattering calculations, we used the RMATRIX1 program [16].*

The channel functions $\Phi_i$ are the input parameters for this program. It is well known that the Hartree-Fock model does not provide a good description of the ground and excited states of neutral alkaline-earth atoms. Since an adequate description of the atomic structure is a prerequisite for an accurate scattering calculation, we have chosen to represent the Mg ground and excited states by CI wave functions. On other hand, as mentioned previously, an important consideration with regard to the occurrence of pseudo-resonances in R-matrix calculations is the need for a consistent description of the $N$-electron target within this $(N+1)$-electron collision problem. There is no unique recipe for achieving this goal, but a good approximation is obtained if one additional electron is coupled to every important configuration in the target description and if the close-coupling expansion (1) contains the maximum number of target physical- and pseudo-states [17, 18]. In extended calculations like the present one, it can become difficult to limit the matrix dimension to a tractable size. Accordingly, it is necessary to apply some restrictions to the basis states used in CI description of the target states.

### *A. Target states*

A good systematic representation of wave functions for atoms with two valence electrons may be achieved in a frozen-core approximation by using the corresponding ionic orbitals for construction of the basis functions and introducing a phenomenological polarization potential for the core, to take into account the core-valence correlation. This variant of the CI method reduces the problem to a two-electron calculation and has been widely used in a variety of calculations. We have used this method for representing the target wave functions for $e$ + Ca [8], $e$ + Sr [10] and $e$ + Mg [3] scattering, as well as for representing the autoionizing states in the cases of $e + Ca^+$ scattering [11] and two-photon ionization of Mg [19]. The details of these calculations are given in the above references.

### *B. Collision calculations*

As demonstrated in the RMPS works on $e$ + Be scattering [17], it is advantageous to keep as many target states as possible in the close-coupling expansion (1), in order to control the effect of pseudo-resonances. In total, the above-mentioned configurations in the reduced basis give rise to 35 target states, taking into account the $LS\pi$ structure. It is convenient to divide these states in 21 physical states with energies corresponding to the experimental ones and 14 pseudo-states with energies lying close to the ionization

threshold and in the adjacent continuum. The latter are included in the close-coupling expansion in order to (i) represent the coupling to the target continuum and (ii) control the effect of unphysical resonances. Although pseudo-resonances can still occur due to the thresholds associated with the pseudo-states, their effect can be drastically reduced by keeping as many states as possible in the expansion [18]. But our control calculations show that the pseudo-resonance structure is considerably reduced already with the inclusion of only one pseudo-state for each target symmetry, and the further addition of other pseudo-states only slightly affects the resulting cross sections. Therefore, to save computation time in our final calculations, we retained in the close-coupling expansion (1) all 21 physical states and some pseudo-states for each angular symmetry of the target. All these pseudo-states have energies close to the ionization threshold and are assumed to simulate the rest of the physical states of Mg not included in the close-coupling expansion. In all, we have 35 states in the first sum of expansion (1): 21 physical states and 14 pseudo-states.

The remaining small oscillations in the cross sections above the ionization threshold were eliminated by convoluting the results with a Gaussian with energy resolution $\Delta E = \sqrt{e}$, where $e$ is the energy (in Rydbergs) above the ionization threshold. Such a procedure was suggested and applied successfully by Meyer *et al.* [20] to smooth out the remaining pseudo-structures in the numerically calculated results.

As discussed above, the sum over bound channels in (1) must include all $(N+1)$-electron states that have parent terms included in the first summation – not more, not less – and this point is crucial for obtaining correct energies for the $(N+1)$-electron system and accurate energy dependences for the cross sections in near-threshold region, especially for weak exchange transitions. Following this prescription is also very important for reducing the pseudo-structure discussed above. In our calculations, an automatic procedure was developed for carrying out the cumbersome selection process for the bound channels.

R-matrix calculations were carried out with following parameters: R-matrix radius $a = 60\, a_0$, a total of $N^{cont} = 20$ continuum basis functions $u_j(r)$ for each orbital angular momentum, and a range $0 \le l \le 14$ for the orbital angular moments of the scattered electron. The R-matrix calculation with full inclusion of exchange was carried out for all partial waves with $L \le 10$, and partial wave contributions for $L > 10$, if necessary, were estimated by a top-up procedure via a geometric series.

**Results and discussion**

In the performed investigation the energetic dependence of the cross section of the superelastic electron scattering on metastable Mg atoms was determined in [6] for the first time. In our experiments the superelastically scattered electrons were detected and the energy dependence of their formation cross section ($Q^s$) was determined by measuring the ratio of the scattering electron current ($i^s$) to the electron beam current ($i_e$), i.e. $Q^s = i^s/i_e$. In [7] presented the dependence of superelastic electron scattering cross section in relative units to the electron energy in eV. The relative uncertainty in determining $Q^s$ ordinate was ~ 8%, the energy scale calibration error – 0.1 eV.

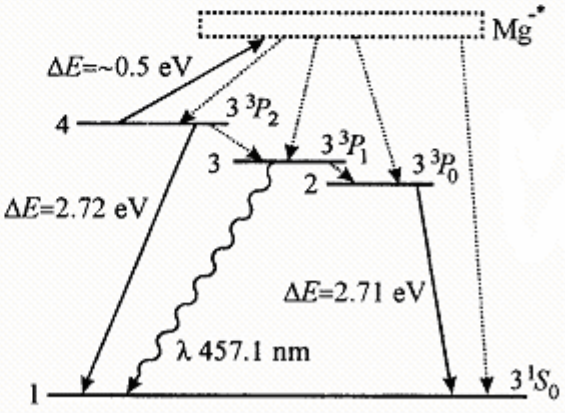


Figure 2. The scheme of the energy levels and transitions. — - transitions, where was measurementd in experiment; ---- - other transitions;

Magnesium atoms have two triplet metastable states $3s3p\ ^3P_0$, $3s3p\ ^3P_2$ with the excitation energies 2.71 eV, 2.72 eV, respectively. Both of these metastable states were present in the atomic beam, while the ratio of their concentration $N^m(3s3p\ ^3P_0) / N^m(3s3p\ ^3P_2) = 1/5$.

As a result of the superelastic electron scattering atoms may pass from the metastable state to the ground state $3s^2\ ^1S_0$. The corresponding reactions can be written in the form:

$$e + Mg\ (3s3p\ 3P0) \rightarrow Mg\ (3s2\ 1S0) + e', \quad (4)$$

$$e + Mg\ (3s3p\ 3P2) \rightarrow Mg\ (3s2\ 1S0) + e'', \quad (5)$$

where $e$ is the incident electron with the energy $E$; $e'$ and $e''$ - superelastically scattered electrons with ($E$+2.71) eV and ($E$+2.72) eV energies respectively. Taking into account that the difference between the energies of the scattered electrons is 0.01 eV, it must be said that the result cross section reflects the average cross section (4) and (5).

In the course of searching for the model of the phenomenon of superelastic electron scattering on the metastable atoms, a certain idea appeared. According to it the superelastic process runs at the following scheme:

$$e^-(E) + A_j^* \rightarrow A^{-*} \rightarrow \tilde{e}^-(E + \Delta E) + A_i^*, \quad (6)$$

where $A^{-*}$ is the negative ion in the excited state.

For Mg atom the reaction (6) can be written in the following way (see also Fig. 2):

$$e(E) + Mg(3^3P_2) \rightarrow Mg^- \rightarrow Mg(3^3P_2) + e(E); \quad (7)$$

$$\rightarrow Mg(3^1S_0) + e(E+\Delta E_1);$$

$$\rightarrow Mg(3^3P_0) + e(E+\Delta E_2);$$

$$\rightarrow Mg(3^1P_1) + e(E+\Delta E_3);$$

$$\downarrow \rightarrow Mg(3\ ^1S_0) + h\nu.$$

We are limited only by the consideration of the metastable $3\ ^3P_2$-state.

In our experiments negative ions were detected and the energy dependence of their formation cross section ($Q_i^-$) was determined by measuring the ratio of the negative-ion current ($i^-$) to the electron beam current ($i_e$), i.e. $Q_i^- = i^-/i_e$.

The result of the experiments is presented in Fig.3 (a), where the ordinate axis corresponds to the negative-ion formation cross-section in relative units, whereas the abscissa axis - to the electron energy in eV. The relative uncertainty in determining the $Q_i^-$ ordinate was ~ 8%, the energy scale calibration error – 1 eV.

In our experiments the spectral line radiation, produced by the interaction of the crossed electron and atomic beams was detected and the excitation function of spectral transfer $3\ ^1S_0 - 3\ ^3P_1$ ($\lambda$ 457.1 nm) was determined. This result is presented in Fig.3 (b), where the ordinate axis corresponds to the cross section of excitation of spectral line in relative units, whereas the abscissa axis – to the electron energy in eV. The relative uncertainty in determining the $Q^{ex}$ ordinate was ~ 12%, the energy scale calibration error – 0.1 eV. In our opinion, this radiation could be caused by the decay of the excited states of the negative ions into excited $3\ ^3P_1$-state of Mg atom.

The analysis of Figs.3 (a, b) shows that the form of curves changes considerably in he energy region less then 0.5 eV. Thus, the investigation of the superelastic process in this field becomes especially important. Hence, the experiments on superelastic electron scattering in the region of energies 0.15-2.0 eV have been carried out. The obtained result is shown in Fig.3 (c), where the ordinate axis corresponds to superelastic electron scattering cross section in relative units, whereas the abscissa axis – to the electron energy in eV. The relative uncertainty in determining the $Q^s$ ordinate was ~ 8%, the energy scale calibration error – 0.1 eV.

The examination of Figs.3 (a, b, c) indicates the similarity of the curves given. The logical explanation of this fact may be the validity of the model proposed here. According to this model, the process of superelastic electron scattering from

metastable atoms includes an intermediate stage of formation and decay of the negative ion (see reaction (7)).

We used R-matrix method with pseudo-states [17] in 35-state intermediate-coupling approximation for the calculation of electron-impact excitation cross sections in neutral Mg. A configuration interaction representation with frozen core was used for the outer electrons of the target. As was mentioned above the close-coupling expansion includes the 21 physical target states and 14 pseudo-states in the *LSJ*-coupling scheme.

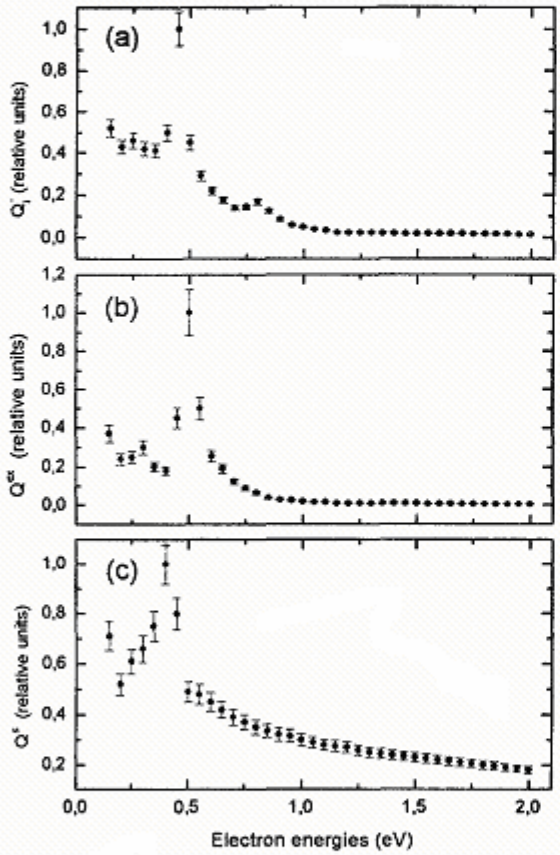


Figure 3. (a) Energy dependence of the effective cross-section of $Mg^-$ negative ions formation. (b) Excitation function of spectral transition $3\,^1S_0 - 3\,^3P_1$ (λ 457.1 nm). (c) Energy dependence of the cross section of superelastic electron scattering by metastable $3\,^3P_{0,2}$ states of magnesium atom.

The present calculations is a direct extension of our previous *LS* calculations [3] of electron-impact excitation of the Mg atom to the case of intermediate coupling and have been undertaken in support of recent measurements of super-elastic scattering on the metastable $3s3p\,^3P_{0,2}$ levels of Mg, about which one the speech went above.

In experiment mentioned before the part of integral cross section for superelastic scattering in the range of scattering angles from 0 to ~ 0.5 rad was measured. Energy dependence of these cross sections for superelastic scattering from metastable $3\,^3P_{0,2}$ states of Mg atom was obtained in the near-threshold region.

Figure 4 (a) present the results of our calculations for the $(3s^2)\,^1S_0 - (3s3p)\,^3P_0$, $(3s^2)\,^1S_0 - (3s3p)\,^3P_1$, $(3s^2)\,^1S_0 - (3s3p)\,^3P_2$ transitions. As expected, the intermediate-coupling effects were found to be small, and integral cross sections for individual *J*-levels agree well with *LS*-calculations [3] if the corresponding statistical factor is taken into account.

Figure 4 (b) compares the theoretical cross sections for the transition $(3s3p)\,^3P_2$–$(3s^2)\,^1S_0$ with the relative measurements mentioned before. The theoretical results were obtained by integrating the differential cross sections in the range of scattering angles from 0 to 25°. The results of relative measurements were normalized to our cross section at energy of 2 eV. We see that there is a good agreement in the energy dependence of experimental and theoretical cross section at energies greater than 0.4 eV, but larger difference is observed in the near-threshold region. The origin of this difference is not clear, and further both theoretical and experimental investigations are desirable in this respect.

The $(3s3p)\,^3P_{0,2} - (3s^2)\,^1S_0$ de-excitation integral cross sections is presented on Fig. 5. As it is visible from a Fig. 5, the de-excitation cross-sections for transitions $(3s3p)\,^3P_0 - (3s^2)\,^1S_0$ and $(3s3p)\,^3P_2 - (3s^2)\,^1S_0$ iterate one another almost exactly. The small differences are watched during cross sections are watched only in area near a threshold. Let's mark, that the cross section of transition $(3s3p)\,^3P_1 - (3s^2)\,^1S_0$ essentially also coincides cross-section of transition $(3s3p)\,^3P_0 - (3s^2)\,^1S_0$. As the course of a

curves smoothly varying, without availability of any structure is visible from a figure, in the field of 0.5 eV see. It is qualitatively a course of integral cross section iterates a course of toted differential cross section, introduced in a Fig. 4 (b). Apparently, for explanation of qualitative difference of the theory with experiment in the field of energies smaller ~ 0.5 eV it is necessary to conduct padding examinations.

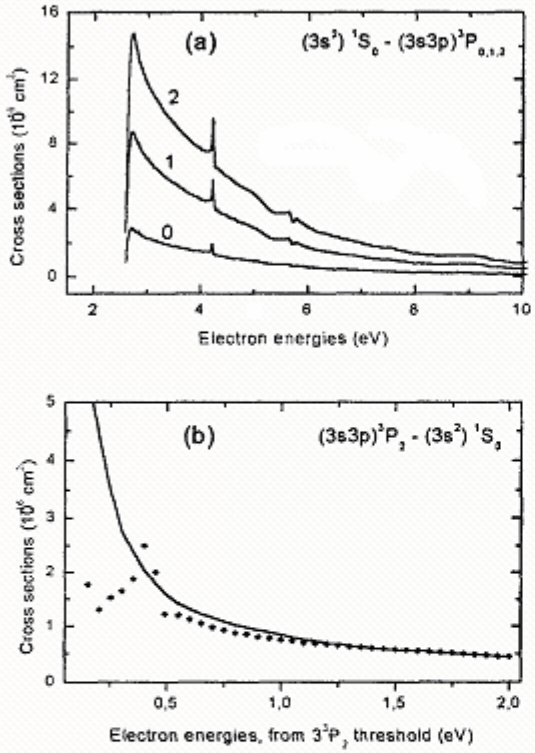


Figure 4. (a) Excitation cross sections for the $(3s^2)\ ^1S_0 - (3s3p)\ ^3P_0$, $(3s^2)\ ^1S_0 - (3s3p)\ ^3P_1$, $(3s^2)\ ^1S_0$– $(3s3p)\ ^3P_2$ transitions (curve 0, 1, 2, respectively). (b) Comparison of the experimental cross section (◆) with the *R*-matrix calculations for the $(3s3p)\ ^3P_2 - (3s^2)\ ^1S_0$ transition of Mg.

In a Fig. 6 the cross-sections of an elastic scattering for states $(3s3p)\ ^3P_2$ (Fig. 6 (a)) and $(3s3p)\ ^3P_0$ (Fig. 6(b)) represented. The availability on a curves of transitions $(3s3p)\ ^3P_0 - (3s3p)\ ^3P_0$ and $(3s3p)\ ^3P_2 - (3s3p)\ ^3P_2$ of a broad sag with a minimum in the field of 0.4-0.5 eV can obliquely testify to formation of an negative ion of magnesium. The subsequent decay of this ion in underlying states can result in to diminution of sections of elastic collisions.

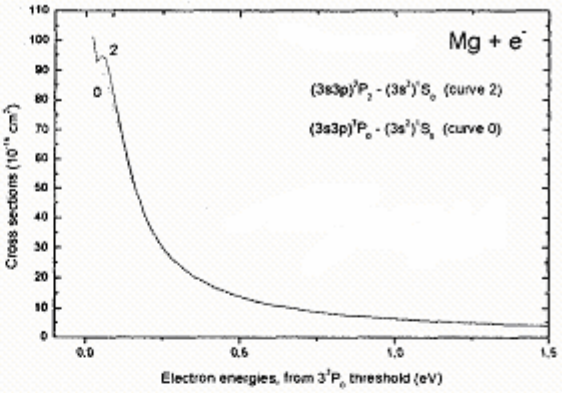


Figure 5. The de-excitation $(3s3p)\ ^3P_{0,2} - (3s^2)\ ^1S_0$ cross sections: —— - $^3P_2 - ^1S_0$ transition; ------$^3P_0 - ^1S_0$ transition.

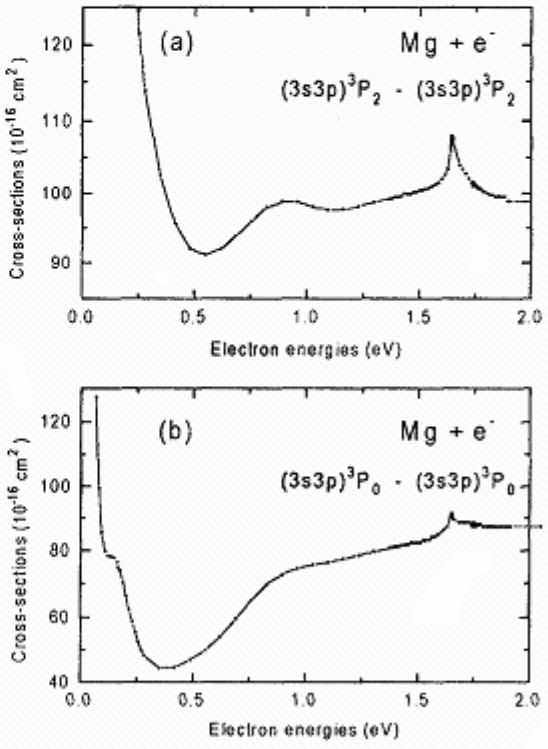


Figure 6. Excitation cross sections for the $(3s3p)\ ^3P_2 - (3s3p)\ ^3P_2$ elastic collision processes with $3^3P_2$ metastable state.

So, it is possible to make some deductions:

1) The experimental measurements of cross sections of formation of negatively

ionized Mg-atoms, functions of excitation of spectral transition $(3s^2)\ ^1S_0 - (3s3p)\ ^3P_1$ and differential cross sections of an elastic scattering testify to availability of particular structure in the field of energies ~ 0.5 eV above a threshold of excitation. The origin of this structure can be bound to formation of a negative ion of magnesium, though, basically, the opportunity of the contribution and other effects is not eliminated.

2) The theoretical calculations of differential sections conducted in *LSJ* coupling approach, and integrated on angles, practically have coincided with experiment (to within 10 %) in the field of energies from 2 up to 0.5 eV. However, to detect structures apparent on experiment, it was not possible to us. Probably, it is bound to features and (/or) deficiencies of theoretical approach, used by us. The area of conducted examinations is very close to a threshold, where manifestation of different threshold effects, as is known, is possible. At the same time, the availability of sags on curves of excitation cross sections of a elastic transitions $(3s3p)\ ^3P_0 - (3s3p)\ ^3P_0$ and $(3s3p)\ ^3P_2 - (3s3p)\ ^3P_2$ in the area of 0.5 eV can obliquely testify to formation of negatively ionized atoms of magnesium and, thus, confirm experiment.

In any case, as mentioned above, it is desirable to conduct padding examinations, both experimental, and theoretical, with the purpose of clearing up of the mechanism of process of excitation from metastable states by electron impact in threshold region.

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# ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ ТА R-МАТРИЧНІ РОЗРАХУНКИ ПЕРЕРІЗІВ НАДПРУЖНОГО РОЗСІЯННЯ ЕЛЕКТРОНІВ НА МЕТАСТАБІЛЬНИХ СТАНАХ $(3s3p)\ ^3P_{0,2}$ Mg

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В цій статті наведені результати експериментальних і теоретичних досліджень надпружного розсіяння на метастабільних станах $3s3p\ ^3P_{0,2}$ атома Mg. Експеримент був здійснений методом перехресних електрон-атомних пучків. В експерименті була виміряна частина інтегрального перерізу надпружного розсіяння для кутів від 0 до ~0.5 рад. Отримано енергетичну залежність перерізів надпружного розсіяння на метастабільних станах $3s3p\ ^3P_{0,2}$ атома Mg в припороговій області енергій від 0.15 до 3 еВ. Відносна точність отриманих перерізів оцінюється в ~ 8%, похибка в калібровці енергетичної шкали менша за 0.1 еВ. Виявлена резонансна структура при енергіях електронів ~ 0.45 еВ. Для розрахунку перерізів збудження електронним ударом нейтрального Mg ми використали R-матричний метод з псевдостанами в наближенні 35 станів проміжного зв'язку. В розклад сильного зв'язку були включені 21 фізичні стани мішені і 14 псевдостанів в схемі *LSJ*- зв'язку. Отримано хороше узгодження в енергетичній залежності експериментального і теоретичного перерізів при енергіях, більших за 0.4 еВ, але спостерігаються значні відмінності в області менших енергій. Природа цих розходжень не зовсім зрозуміла і потребує додаткових теоретичних і експериментальних досліджень.