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Distorted-wave models in positron impact ionization of atoms

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Abstract

This paper compares the best distorted-wave model results with the most recent experimental data in positron ionization of atomic hydrogen and noble gases. The re-calibration of the experimental measurements yields good agreement with our DCPE5 model at high energies for all the target atoms studied. © 2002 Published by Elsevier Science B.V.

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1. Introduction

In a recent paper [1], we proposed a distorted-wave model, CPE4, that gave reliable results for positron ionization of the noble gases as well as hydrogen. However, the agreement with the experimental data for H and Ne was not as good as for the other systems.

Since that paper was submitted there has been a re-calibration of some of the latest experimental data [2] which modifies some of the analysis of our earlier paper. Building on our experience from that work we are proposing a new model which produces results in better agreement with the revised experimental data than the CPE4 model.

A review of the previous experimental and theoretical work was given in [1] and will not be repeated here.

2. Theoretical models

In our previous papers we employed a number of CPE or DCPE models (CPE stands for coulomb plus plane waves with full energy range and DCPE stands for distorted-wave CPE). We found that the final state corresponding to the ejected electron being faster than the scattered positron produces only a small contribution to the ionization cross sections and we did not examine the effect of changing our representation for that final state. In all our models the slower scattered positron was represented as a simple coulomb wave in the field of the residual ion, while the faster ejected electron was a coulomb wave in the field of two positive charges (the positron and the residual ion). Our effort was directed towards a correct representation of the incident channel and of the final state for the case when the scattered positron moves faster than the ejected electron.

Our model requires three potentials V_i, V_e and V_f to calculate the distorted waves. V_i represents the potential seen by the positron in the initial channel

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while V_e and V_f are the potentials for the electron and positron in the final channel, respectively. In our last paper [1] the CPE4 model used $V_e = -(1 - E_e/E_{ef})/r$, where E_e and E_f are the energies of the free particles in the final channel while E_{ef} is given by

$$E_{ef} = E_e + E_f - 2\sqrt{E_e E_f}. \tag{1}$$

We found that this potential along with the choice of $V_i = V_f = 0$ produced the best results. The use of this form of V_e was suggested by the experimental results of Kover et al. [3]. Requiring V_i and V_f to be the same potential was based on experience with distorted-wave models for electron scattering. The CPE model also used plane waves for the positron and a simple coulomb wave for the ejected electron [4].

In this paper we investigate another model with the same properties as CPE4 but using more physically realistic potentials for the positron. We take $V_i = V_f = V_{st} + V_{pol}$ where V_{st} is the atomic static potential seen by a positron in the initial channel and V_{pol} is the polarized-orbital polarization potential of McEachran et al. [5]. We call this model DCPE5.

3. Results and discussion

Fig. 1 shows the agreement of our CPE, CPE4 and DCPE5 models with the experiment for atomic hydrogen. The two sets of experiments of Jones et al. [6] and Hofmann et al. [7] (the results of Hofmann et al. replace the earlier published data of Weber et al. [8]) are in good agreement with each other and also with the new data of DCPE5.

Figs. 2–6 show the comparison between our CPE, CPE4 and DCPE5 results and the experimental measurements for noble gases. The exper-

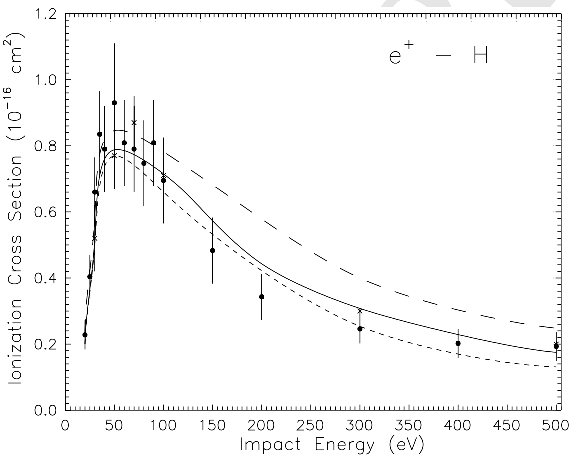

Fig. 1. e$^+$–H. Experiment: (•) Jones et al. [6]; (∗) Hofmann et al. [7]. Theory: (—) DCPE5; (– – –) CPE4; (- - -) CPE.

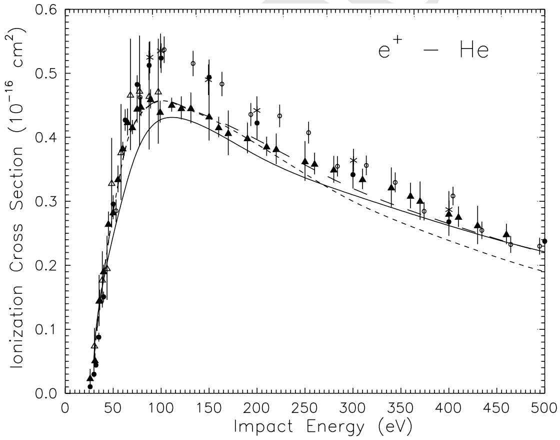

Fig. 2. e$^+$–He. Experiment: (•) Knudsen et al. [9], (○) Moxom et al. [10]; (▲) Fromme et al. [12]; (△) Mori and Sueoka [14]; (∗) Jacobsen et al. [13]. Theory: (—) DCPE5; (– – –) CPE4; (- - -) CPE.

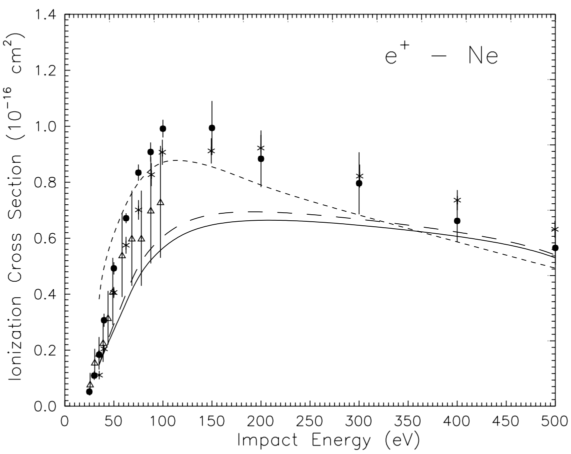

Fig. 3. e$^+$–Ne. Experiment: (•) Knudsen et al. [2,9]; (△) Mori and Sueoka [14]; (∗) Jacobsen et al. [13]. Theory: (—) DCPE5; (– – –) CPE4; (- - -) CPE.

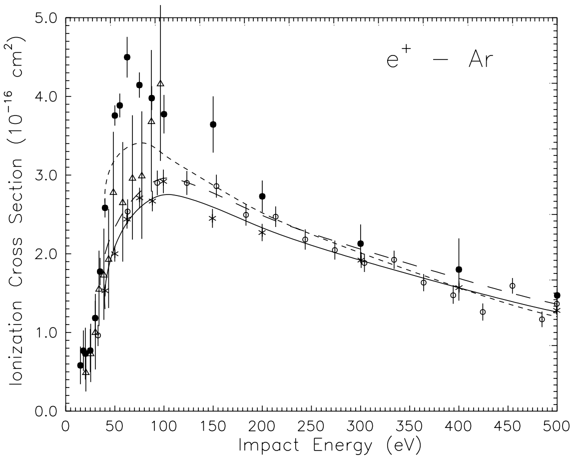

Fig. 4. e$^+$–Ar. Experiment: (•) Knudsen et al. [9]; (○) Moxom et al. [2,10]; (△) Mori and Sueoka [14]; (∗) Jacobsen et al. [13]. Theory: (—) DCPE5, (– – –) CPE4; (- - -) CPE.

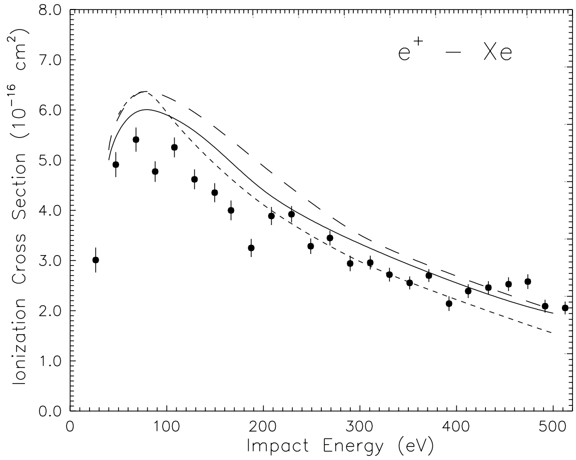

Fig. 6. e$^+$–Xe. Same as for Fig. 5.

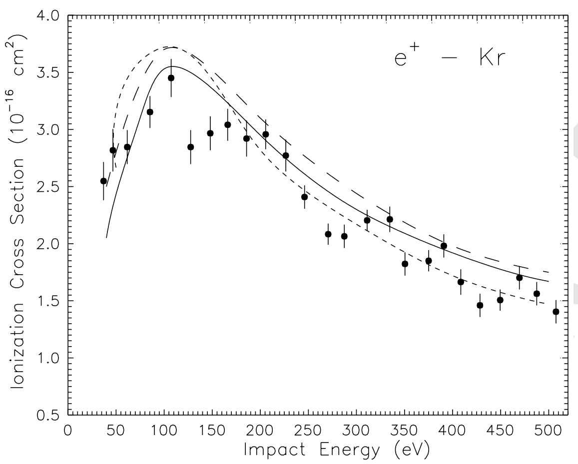

Fig. 5. e$^+$–Kr. Experiment: (•) Kara et al. [2,11]. Theory: (—) DCPE5; (– – –) CPE4; (- - -) CPE.

imental data from the University College London group were recently re-calibrated [2] for Ne, Ar, Kr and Xe. This work lowered by 19% the Ne results of Knudsen et al. [9], increased by 2% the Ar data of Moxom et al. [10] and lowered the experimental results of Kara et al. [11] by 7% for Kr and by 14% for Xe.

For He our models agree best with the low energy measurements of Fromme et al. [12], which converge with the results of Moxom et al. [10] and Jacobsen et al. [13] above 250 eV, but fall somewhat below the more recent experiments in the region of the peak of the cross sections. For Ne our CPE model is in best agreement with the experiment, while the CPE4 and DCPE5 results fall below the measurements at lower energies though the data of Mori and Sueoka [14] indicate a peak value consistent with these latter models. The re-calibrated experimental data of [9] are now in in good agreement with the results of [13] and have a very similar shape to the theoretical data. For Ar the theoretical models are in good agreement with the recent measurements of Moxom et al. [10] and Jacobsen et al. [13]. Another case of good agreement is between our DCPE5 model and the re-calibrated results of Kara et al. [11] for Kr. For Xe the agreement between our DCPE5 data and the experiment is good only at higher energies, while near the peak the theoretical results are above the re-calibrated experimental data. DCPE5 model seems to produce results in closest overall agreement with the Xe experiment.

4. Conclusions

CPE and CPE4 are relatively simple models in the sense that they do not require elaborate descriptions of the various scattering channels. Apart from the need for accurate representation of the correlation between the faster scattered positron and the slower ejected electron (in the case of CPE4), all the particles involved in the ionization system are represented through plane and coulomb waves. DCPE5 is more elaborate as it describes the positron through waves distorted in the static plus polarization field of the atom.

Comparing the existing experimental data against a single theoretical model can be a guiding factor in the assessment of various measurements. Although it is possible that various effects will add or cancel in different ways for different targets, some consistency is expected in cases where the theory uses exactly the same approximation. For instance, our CPE4 model always produced lower results than our CPE model in the region of the cross section maximum, while they were higher at higher energies. Also our DCPE5 model is always below CPE4 at low energies and in good agreement with CPE4 at high energies. Having a single theoretical model enables the comparison of experimental cross sections from different experimental groups and for different targets.

Our figures show that our model DCPE5 is in best agreement with the latest experimental data. The only case where this model does not work well is the ionization of neon, in which case our DCPE5 data agree with the latest experiments only at the highest energies shown. For that atom CPE seems to be the theoretical model which agrees best with experiment.

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