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## 2 Distorted-wave models in positron impact ionization of atoms

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### 7 Abstract

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

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

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

27 A review of the previous experimental and the-  
28 oretical work was given in [1] and will not be re-  
29 peated here.

### 2. Theoretical models

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

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

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52 while  $V_e$  and  $V_f$  are the potentials for the electron  
 53 and positron in the final channel, respectively. In  
 54 our last paper [1] the CPE4 model used  $V_e =$   
 55  $-(1 - E_e/E_{ef})/r$ , where  $E_e$  and  $E_f$  are the energies  
 56 of the free particles in the final channel while  $E_{ef}$  is  
 57 given by

$$E_{ef} = E_e + E_f - 2\sqrt{E_e E_f}. \quad (1)$$

60 We found that this potential along with the choice  
 61 of  $V_i = V_f = 0$  produced the best results. The use of  
 62 this form of  $V_e$  was suggested by the experimental  
 63 results of Kover et al. [3]. Requiring  $V_i$  and  $V_f$  to be  
 64 the same potential was based on experience with  
 65 distorted-wave models for electron scattering. The  
 66 CPE model also used plane waves for the positron  
 67 and a simple coulomb wave for the ejected electron  
 68 [4].

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

### 77 3. Results and discussion

78 Fig. 1 shows the agreement of our CPE, CPE4  
 79 and DCPE5 models with the experiment for

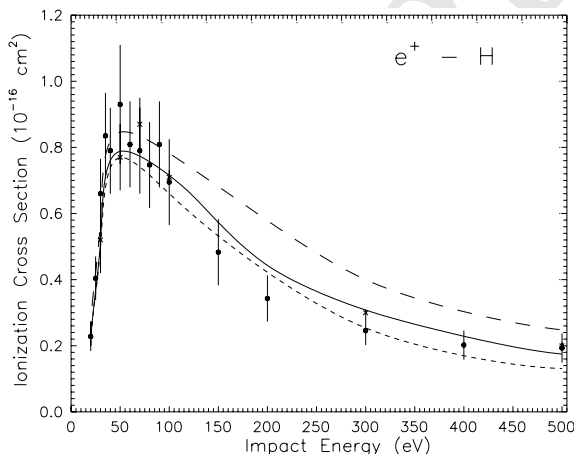


Fig. 1.  $e^+ - H$ . Experiment: (●) Jones et al. [6]; (\*) Hofmann et al. [7]. Theory: (—) DCPE5; (---) CPE4; (---) CPE.

80 atomic hydrogen. The two sets of experiments of  
 81 Jones et al. [6] and Hofmann et al. [7] (the results  
 82 of Hofmann et al. replace the earlier published  
 83 data of Weber et al. [8]) are in good agreement  
 84 with each other and also with the new data of  
 85 DCPE5.

86 Figs. 2–6 show the comparison between our  
 87 CPE, CPE4 and DCPE5 results and the experi-  
 88 mental measurements for noble gases. The exper-

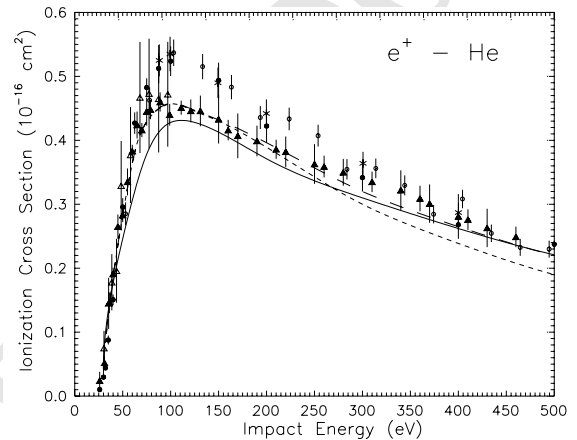


Fig. 2.  $e^+ - He$ . Experiment: (●) Knudsen et al. [9], (○) Moxom et al. [10]; (▲) Fromme et al. [12]; (△) Mori and Sueoka [14]; (\*) Jacobsen et al. [13]. Theory: (—) DCPE5; (---) CPE4; (---) CPE.

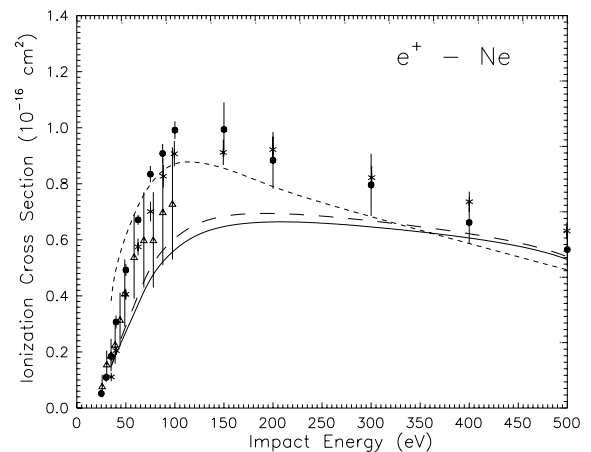


Fig. 3.  $e^+ - Ne$ . Experiment: (●) Knudsen et al. [2,9]; (△) Mori and Sueoka [14]; (\*) Jacobsen et al. [13]. Theory: (—) DCPE5; (---) CPE4; (---) CPE.

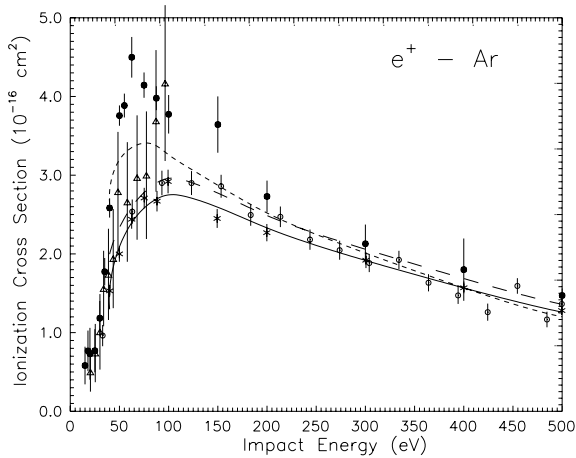


Fig. 4.  $e^+$ -Ar. Experiment: (●) Knudsen et al. [9]; (○) Moxom et al. [2,10]; (△) Mori and Sueoka [14]; (\*) Jacobsen et al. [13]. Theory: (—) DCPE5, (---) CPE4; (- - -) CPE.

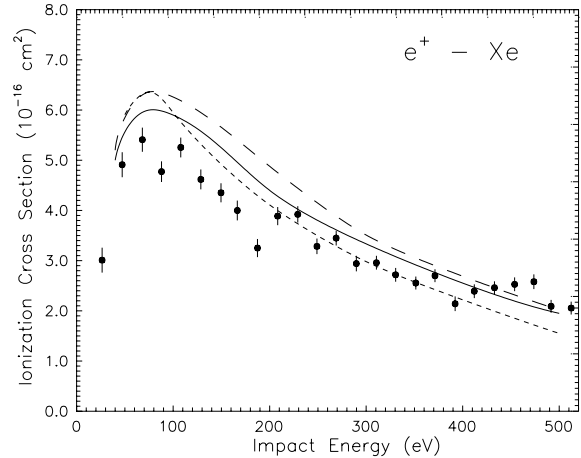


Fig. 6.  $e^+$ -Xe. Same as for Fig. 5.

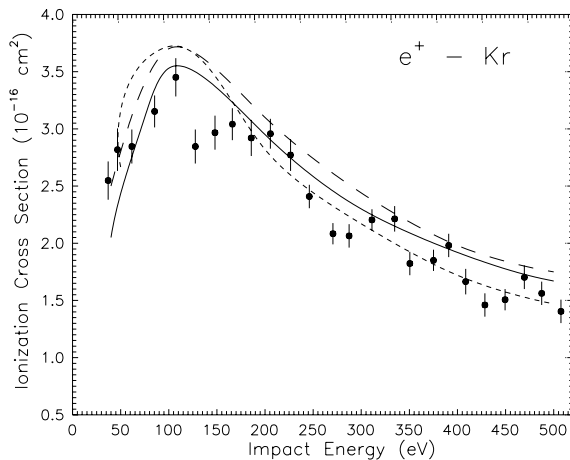


Fig. 5.  $e^+$ -Kr. Experiment: (●) Kara et al. [2,11]. Theory: (—) DCPE5; (---) CPE4; (- - -) CPE.

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

96 For He our models agree best with the low en-  
 97 ergy measurements of Fromme et al. [12], which

converge with the results of Moxom et al. [10] and 98  
 and Jacobsen et al. [13] above 250 eV, but fall some- 99  
 what below the more recent experiments in the 100  
 region of the peak of the cross sections. For Ne 101  
 our CPE model is in best agreement with the 102  
 experiment, while the CPE4 and DCPE5 results fall 103  
 below the measurements at lower energies though 104  
 the data of Mori and Sueoka [14] indicate a peak 105  
 value consistent with these latter models. The re- 106  
 calibrated experimental data of [9] are now in in 107  
 good agreement with the results of [13] and have a 108  
 very similar shape to the theoretical data. For Ar 109  
 the theoretical models are in good agreement with 110  
 the recent measurements of Moxom et al. [10] and 111  
 Jacobsen et al. [13]. Another case of good agree- 112  
 ment is between our DCPE5 model and the re- 113  
 calibrated results of Kara et al. [11] for Kr. For Xe 114  
 the agreement between our DCPE5 data and the 115  
 experiment is good only at higher energies, while 116  
 near the peak the theoretical results are above the 117  
 re-calibrated experimental data. DCPE5 model 118  
 seems to produce results in closest overall agree- 119  
 ment with the Xe experiment. 120

#### 4. Conclusions

121  
 122 CPE and CPE4 are relatively simple models in  
 123 the sense that they do not require elaborate de-  
 124 scriptions of the various scattering channels. Apart

125 from the need for accurate representation of the  
 126 correlation between the faster scattered positron  
 127 and the slower ejected electron (in the case of  
 128 CPE4), all the particles involved in the ionization  
 129 system are represented through plane and cou-  
 130 lomb waves. DCPE5 is more elaborate as it de-  
 131 scribes the positron through waves distorted in the  
 132 static plus polarization field of the atom.

133 Comparing the existing experimental data  
 134 against a single theoretical model can be a guiding  
 135 factor in the assessment of various measurements.  
 136 Although it is possible that various effects will  
 137 add or cancel in different ways for different tar-  
 138 gets, some consistency is expected in cases where  
 139 the theory uses exactly the same approximation.  
 140 For instance, our CPE4 model always pro-  
 141 duced lower results than our CPE model in the  
 142 region of the cross section maximum, while they  
 143 were higher at higher energies. Also our DCPE5  
 144 model is always below CPE4 at low energies and  
 145 in good agreement with CPE4 at high energies.  
 146 Having a single theoretical model enables the  
 147 comparison of experimental cross sections from  
 148 different experimental groups and for different  
 149 targets.

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

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