Positron collisions with alkali-metal atoms

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The total cross sections for positron and electron collisions with potassium, sodium, lithium and rubidium are calculated, employing the modified Glauber approximation. The MG cross sections for positron collision with potassium and sodium at low intermediate energies are found to agree reasonably well with existing experimental data.

Measurements of total cross sections for collision of positron with potassium have been performed only very recently[1]. The experimental results of total cross sections for positron collision by sodium and rubidium have been reported only at this Workshop[2]. In view of the success of the modified Glauber approximation[3] in producing good agreement with experimental data of total cross section in the case of e^+-He, we have performed the calculation of total cross sections for positron (and electron) collisions with potassium, sodium and lithium, again employing the modified Glauber approximation (MG). The model-potential approach[4] will also be used in this calculation to enable the "exact" inclusion of the scattering effects of the core of the alkali atoms. The total cross sections are calculated via the optical theorem.

In alkali atoms, the energy of the first p states of the valence electron is only about 2 eV above its loosely bound s ground state. This results in a strong coupling between these two states and, thus, a very large dipole polarizability for the alkali atoms. Therefore, care must be taken in handling the effect of this particularly strong coupling between these s and p states. In the modified Glauber approximation, the effect of this strong coupling is seen to reflect in the large contribution to the second Born term of the valence-electron-atom scattering from the first p states, especially in the forward direction where the imaginary part of the scattering amplitude is used to calculate the total cross sections. To obtain a greater accuracy for our MG results, we feel that in this particular case of scattering by alkali-metal atoms, the contribution to the second Born term from the intermediate first p states should be evaluated exactly.

The MG total cross sections of positron (and electron) scattering from potassium, sodium and lithium were calculated for scattering energies ranging from about 10 eV to 1000 eV. The MG positron collision with potassium[5] are found to be in good agreement with experimental data available at low intermediate energies at present[1], if one takes into consideration the uncertainty existing in the experimental data due to the inability of discriminating against the elastically scattered

positrons (electrons) near the forward direction. At higher scattering energies (60 - 102.5 eV), the MG values tend to be somewhat smaller than the experimental values, while at lower energies, the MG values tend to be somewhat greater. We have also evaluated exactly the contribution to the second-Born term from the next higher intermediate state (5s for K, 4s for Na and 3s for Li) and we have found that the new values of total cross section only change minutely in comparison to the values obtained with the consideration of the closure approximation for this term. Therefore, we believe that the accuracy of the MG results will not be seriously affected by the employment of the closure approximation for the calculation of the contributions to the second-Born term from other higher excited intermediate states. The MG values of e^+-K collision are found to be consistent also with those obtained by Ward et al.[6] in the 5-state close-coupling calculation.

The MG values of total cross section for electron collision with potassium[5] are also in fair agreement with experimental data at energies higher than 50 eV. The MG electron cross sections are, however, found to be somewhat higher than the positron cross sections. The merging of the two sets of data above 30 eV, as was observed in experimental data[1], does not seem to materialize in our MG calculation. In our opinion, since the difference between the electron and positron MG cross sections above 30 eV is only within 15%, this non-merging of the theoretical data is still acceptable, in view of the possible uncertainty of the experimental data mentioned above. It is worth stressing that in the modified Glauber approximation, the non-merging of the electron and positron cross sections may be understood as to originate from the different contribution in positron and electron scattering to the cross sections from the core scattering.

For collision with sodium, we found that the positron total cross sections are also consistently lower than the electron cross sections for about 10 to 15 percent. The two cross sections did not merge with each other even at an energy as high as 1000 eV. The absolute difference between the electron and positron cross sections now seems to become smaller somewhat, because sodium is lighter than potassium, and therefore, the effect of its less "cumbersome" core would influence the cross sections somewhat less. For collision by lithium, whose core effect is much weaker, our calculation in the MG approximation does indeed provide a merging (within less than 1 to 3 per cent of difference) of the positron and electron cross sections at a rather low energy. It would, therefore, be interesting to also measure the total cross sections for collision by lithium, which have not been available in the literature. We also found that for all three of the alkali targets (K, Na, and Li), the total cross sections for positron and electron collisions, at least within the modified Glauber approximation, did not deviate from each other at some scattering energy above 100 eV and then re-merge at a much higher energy. The MG total cross sections for

positron (electron) scatterings from sodium[5] are found to be in reasonably good agreement with experimental data[1,2] in the range of 10 - 100 eV, and to be consistent with the results of close-coupling calculation[7] at energies lower than 50 eV. Our values of e^+ - Li collision are also consistent with the close-coupling values[7]. Our preliminary results of total cross section for e^+-Rb collision seem to also be consistent with those calculated in the close-coupling approximations[7] below 30 eV, and with experimental data[2] below 50 eV.

Table 1 MG total cross sections in πa_o^2 for e-K, e-Na and e-Li

K			Na			Li	
Energy (eV)	e^+	e^-	Energy (eV)	e^+	e^-	e^+	e^-
11.00	105.85	102.19	10.0	60.20	72.59	76.50	80.90
18.20	90.08	98.85	15.0	61.37	70.08	68.60	71.63
21.10	84.96	94.97	20.0	56.49	63.37	60.19	62.50
28.20	74.52	85.12	30.0	46.85	51.88	47.83	49.40
31.20	70.75	80.98	40.0	39.72	43.79	39.72	40.92
38.40	62.85	71.72	50.0	34.51	38.01	34.06	35.04
48.60	53.97	61.27	54.4	32.65	35.96	32.08	32.99
51.60	51.78	58.75	60.0	30.57	33.68	29.89	30.71
76.75	38.61	44.28	80.0	25.00	27.64	24.14	24.77
102.50	30.76	36.01	100.0	21.25	23.60	20.33	20.85
150.00	22.57	27.44	150.0	15.65	17.56	14.74	15.10
200.00	17.76	22.32	200.0	12.50	14.16	11.66	11.93
300.00	12.60	16.63	300.0	9.06	10.39	8.32	8.51
400.00	9.86	13.48	400.0	7.18	8.31	6.52	6.66
500.00	8.14	11.43	500.0	5.99	6.98	5.38	5.49
800.00	5.40	8.04	800.0	4.06	4.79	3.57	3.64
1000.00	4.45	6.78	1000.0	3.37	3.99	2.93	2.99

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