N90-18963

INELASTIC COLLISIONS OF POSITRONS WITH ONE-VALENCE-ELECTRON TARGETS

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ABSTRACT

The total elastic and positronium formation cross sections of the inelastic collisions between positrons and various one-valence-electron atoms, (namely hydrogen, lithium, sodium, potassium and rubidium), and one-valence-electron ions, (namely hydrogen-like, lithium-like and alkaline-earth positive ions) are determined using an elaborate modified coupled-static approximation. Special attention is devoted to the behavior of the Ps cross sections at the energy regions lying above the Ps formation thresholds.

The interest of many authors in the collisions of positrons with one-valence-electron targets has been enormously increased in the last couple of years. In case of atomic targets (e.g. lithium, sodium, and potassium), various investigations have been carried out in order to calculate the elatsic and excitation cross sections under the assumption that the positronium formation channel,(which is open even at zero incident energy), has irrelevant contribution to the total inelastic cross sections. Particularly, the very recent results of Ward et al {1}, (for a review, see the references therein), have emphasized this argument at energies above 10 eV in comparison with the careful experimental results of the Detroit Group {2}.

For atomic targets (e.g. H, Li, Na, K and Rb) as well as ionic targets (e.g. hydrogen-like, lithium-like and alkaline-earth positive ions), the author has determined total elastic and positronium formation cross sections on a unified basis by virtue of a coupled-static formalism which allows for the switching on of the positronium polarisation potentials. He also employed a restricted coupled-static technique (with symmetrical reactance matrices) for the treatment of the positron collisions with alkali atoms and alkaline-earth positive ions. Tables 1 and 2 contain the results of this treatment. It is obvious that the role of the Ps channel increases with the size of the target and that interesting behaviors (resonances) show up in most cross sections of the problems considered. In table 3 we find the values of the elastic cross sections of the collisions of positrons with hydrogenlike ions determined at energies below the Ps threshold of e^+- H scattering. Figs. 1 and 2 show the variation of the total elastic and Ps formation cross sections with a parameter δ related to the incident energy(k_1^2) by $k_1^2 = 13.6\ (\sqrt{E_{Ps}-E_T}+\delta)^2$ eV. From the first figure we realize that the elastic cross sec-

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Table 1

Total cross sections (in a_0^2) of the inelastic collisions of positrons with alkali atoms calculated by the restricted coupled-static approximation.

k_1^2 (eV)	e^+- Li σ_{11}	e^+- Li σ_{12}	e^+- Na σ_{11}	e^+- Na σ_{12}	e^+- K σ_{11}	e^+- K σ_{12}	e^+- Rb σ_{11}	e^+- Rb σ_{12}
0.1	941.469	148.392	645.270	77.975	719.379	217.267	1612.455	1475.514
0.3	801.315	91.865	655.901	45.666	320.254	221.573	7849.010	3961.333
0.5	738.766	75.972	704.790	28.423	455.333	297.469	6953.694	1614.430
0.7	680.242	83.902	710.515	100.675	4204.943	124.410	4599.199	1087.248
0.9	645.286	88.222	964.165	460.303	622.312	102.141	4072.006	1145.076
1.0	636.696	90.263	691.374	89.349	2482.024	367.222	2522.331	1153.929
3.0	369.131	74.413	458.965	61.487	599.794	176.554	1316.109	52.054
5.0	230.472	58.970	258.300	47.046	399.824	109.816	437.963	60.365
7.0	152.337	47.781	144.570	51.064	253.556	102.289	269.108	77.717
9.0	103.806	32.341	107.874	58.372	189.309	115.816	313.231	75.563
10.0	85.049	25.222	55.260	59.528	129.054	100.086	282.181	122.521
20.0	27.835	3.558	4.402	4.833	32.591	36.379	76.223	39.655
30.0	17.929	1.080	2.198	1.459	12.713	8.080	129.875	4.456
40.0	13.760	0.426	2.044	0.574	11.357	0.624	43.668	14.385
50.0	11.362	0.191	1.818	0.253	10.137	0.249	43.061	13.132

Table 2

Total cross sections (in a_0^2) of the inelastic scattering of positrons by the alkaline-earth positive ions determined by the restricted coupled-static approximation. * denotes the switching on of the Ps polarisation potentials to the second channel.

k_1^2 (eV)	e^+- Be^+ scattering σ_{11}	σ_{12}	σ_{12}^*	k_1^2 (eV)	e^+- Mg^+ scattering σ_{11}	σ_{12}	σ_{12}^*
11.5	349.684	0.209	1.731	8.0	449.703	3.451	1.929
12.0	339.914	3.593	4.723	8.5	260.996	5.410	30.170
12.5	349.797	2.817	11.907	9.0	385.611	11.378	58.770
13.0	352.294	4.732	16.587	9.5	320.991	19.072	70.328
13.5	354.200	6.577	19.231	10.0	225.587	26.777	42.952
14.0	354.003	8.605	19.569	10.5	231.598	36.047	43.225
14.5	353.272	10.740	19.796	11.0	235.333	40.801	59.710
15.0	353.474	12.869	20.425	11.5	410.345	54.903	52.387
15.5	354.390	14.911	21.175	12.0	369.965	46.490	55.320
16.0	354.508	16.847	21.825	12.5	419.207	56.612	48.898
16.5	352.991	18.664	22.187	13.0	385.161	53.447	48.120
17.0	350.434	20.266	22.166	13.5	380.952	56.693	45.922
17.5	347.780	21.531	21.850	14.0	378.774	58.397	43.702
18.0	345.378	22.368	21.366	14.5	375.177	58.809	41.084
18.5	342.908	22.732	20.754	15.0	370.471	58.042	38.170
20.0	331.051	21.714	18.231	20.0	302.705	30.500	15.966
30.0	271.310	7.649	5.198	30.0	284.952	4.774	2.252
40.0	233.141	2.159	1.315	40.0	248.220	0.790	0.658
	e^+- Ca^+ scattering				e^+- Sr^+ scattering		
5.0	262.036	26.351	159.151	4.0	554.086	38.908	136.721
5.5	553.234	60.094	83.648	4.5	894.376	43.705	65.746
6.0	127.552	82.120	69.628	5.0	1076.244	48.218	99.283
6.5	489.814	98.024	83.999	5.5	946.441	45.595	197.243
7.0	212.229	124.445	99.102	6.0	642.249	39.480	204.168
7.5	524.693	118.759	134.058	6.5	524.357	166.505	116.357
8.0	514.025	138.860	107.796	7.0	644.844	136.062	206.023
8.5	395.009	117.034	151.287	7.5	369.897	119.481	109.886
9.0	506.416	118.065	127.981	8.0	428.580	137.142	111.962
9.5	578.446	132.536	131.192	8.5	461.477	160.096	73.996
10.0	308.040	153.003	112.717	9.0	310.432	98.997	110.089
10.5	500.374	99.159	73.772	9.5	525.656	82.694	48.696
11.0	376.535	111.713	100.039	10.0	585.142	68.910	104.221
11.5	472.790	90.852	86.591	10.5	569.778	61.807	38.790
20.0	325.448	23.483	19.897	11.0	539.941	110.756	49.981
30.0	329.861	1.999	4.303	20.0	412.929	17.725	22.572
40.0	254.766	5.278	4.217	30.0	353.306	4.776	8.106
50.0	198.221	5.232	4.140	40.0	259.249	2.721	3.143

tions of all ions decrease monotonically with the increase of δ, while the Ps cross sections assume the opposite behavior and decrease (almost an order of magnitude) with the increase of Z.

In Figs. 3 and 4 we present two examples for our last investigation, namely the collisions of positrons with lithium-isoelectronic ions. There we plot the relation between the total Ps cross sections and the incident energy for e^+- C^{3+} and e^+- N^{4+}, respectively, with and without switching on the Ps polarisation potentials. It is clear that these potentials shift the maxima of the pure coupled-static cross sections towards the Ps thresholds {3}. Finally, we hope that the present work would draw the attention of positron community to the field of positron-ion collisions and encourage the theorists to investigate the problems tackled here using more elaborate techniques.

ACKNOWLEDGMENT

I am extremely indebted to the Deutsche Forschungsgemeinschaft

TABLE 3 - *Total elastic cross-sections (in a_0^2) of the collisions of positrons with different hydrogenlike targets at energies below the Ps formation threshold in e^+-H scattering.*

k_i^2 (eV)	Targets					
	H	He^+	Li^{2+}	Be^{3+}	B^{4+}	Na^{10+}
0.1	4.229	0.437	0.1110	0.0415	0.01920	0.001196
0.5	4.113	0.434	0.1108	0.0414	0.01917	0.001195
1.0	3.978	0.430	0.1100	0.0413	0.01914	0.001195
1.5	3.856	0.425	0.1095	0.0411	0.01910	0.001194
2.0	3.738	0.421	0.1090	0.0410	0.01907	0.001194
3.0	3.631	0.417	0.1085	0.0409	0.01903	0.001193
3.5	3.437	0.413	0.1080	0.0408	0.01900	0.001193
4.0	3.350	0.409	0.1075	0.0407	0.01896	0.001192
4.5	3.267	0.406	0.1070	0.0406	0.01893	0.001192
5.0	3.189	0.402	0.1065	0.0405	0.01889	0.001191
5.5	3.115	0.398	0.1060	0.0403	0.01886	0.001191
6.0	3.046	0.395	0.1055	0.0402	0.01882	0.001190
6.5	2.978	0.391	0.1050	0.0401	0.01879	0.001189

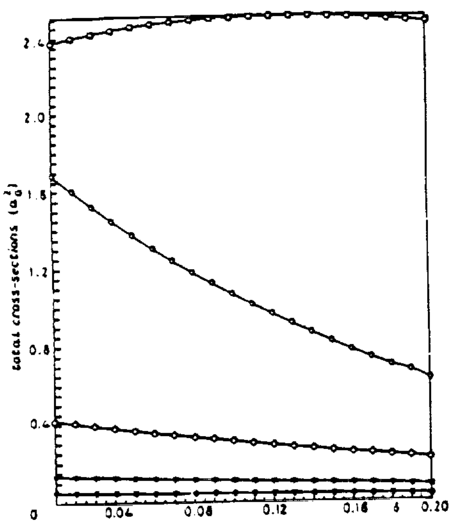

Fig. 1. - Comparison between the total elastic cross-sections on the inelastic collisions of positrons with different hydrogenlike targets. □ e^+-H, ○ e^+-He^+, ◇ e^+-Li^{2+}, • e^+-Be^{3+}, ● e^+-B^{4+} scattering.

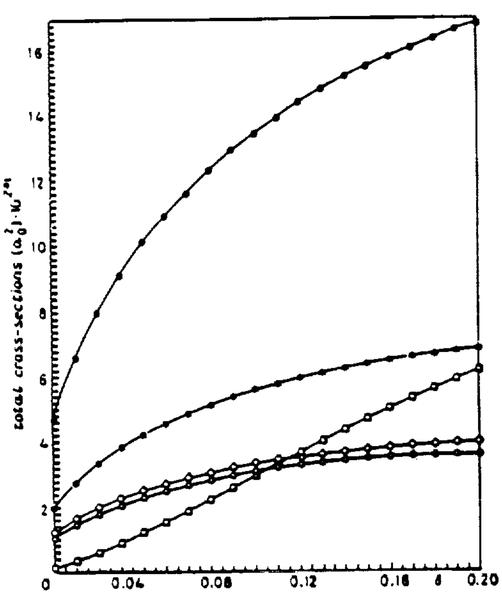

Fig. 2. - Comparison between the total positronium formation cross-sections of the inelastic collisions of positrons with different hydrogenlike targets. □ e^+-H, ○ e^+-He^+, ◇ e^+-Li^{2+}, • e^+-Be^{3+}, ● e^+-B^{4+} scattering.

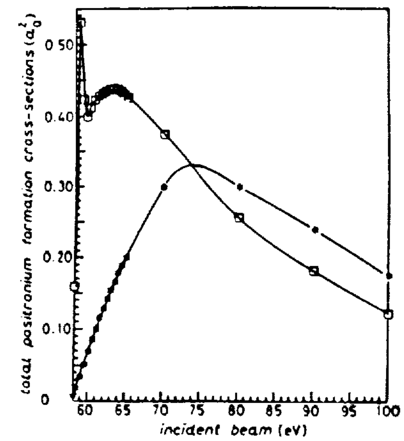

Fig. 3.

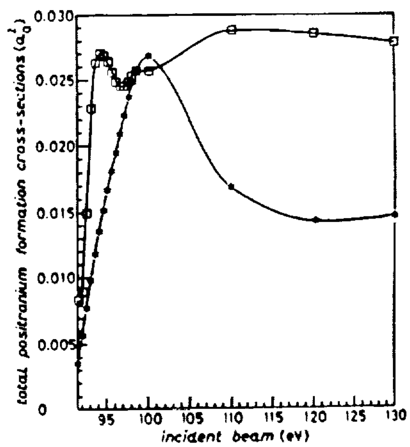

Fig. 4.

Fig. 3. - Variation of the total positronium formation cross-section of e^+-C^{5+} inelastic scattering with the incident energy. • pure coupled-static calculations. □ coupled-static with Ps polarization.

Fig. 4. - Variation of the total positronium formation cross-section of e^+-N^{6+} inelastic scattering with the incident energy. • pure coupled-static calculations. □ coupled-static with Ps polarization.

for providing me with the financial support required for visting this Workshop and the XVI. ICPEAC.

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