Low-energy scattering of antihydrogen by helium and molecular hydrogen

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The experimental work at CERN on antihydrogen ($\bar{\mathrm{H}}$) has focussed attention on interactions involving $\bar{\mathrm{H}}$.

The first calculations we carried out were on $\mathrm{H}\,\bar{\mathrm{H}}$ scattering at very low energies [1,2].

We are in the process of calculating cross sections for the three rearrangement reactions

$$\mathrm{He} + \bar{\mathrm{H}} \rightarrow \mathrm{He}^+\bar{p} + Ps \text{ or } \mathrm{He}\bar{p} + \mathrm{e}^+ \text{ or } \alpha\bar{p} + Ps^-$$

at very low energies. These cross sections are simply related to the T-matrix

$$T_{fi} = \langle \Phi_f | V_f | \Psi^{(+)}_{\mathbf{k}_i} \rangle,$$

where $\Psi^{(+)}_{\mathbf{k}_i}$ is the exact scattering wave function for the incident energy under consideration. V_f is the potential that couples the two systems resulting from the scattering, e.g. $\mathrm{He}^+\bar{p}$ and Ps. Φ_f is the final wave function if V_f is set to zero.

As in ref. [2], the exact scattering wave function was approximated by the wave function for the entrance channel, calculated using the Born–Oppenheimer (BO) approximation.

The leptonic wave function for the incident channel was calculated very accurately using basis functions, χ_i, of the form

$$\chi_i = \left(\frac{1}{2\pi}\right)^{\frac{3}{2}} [\lambda_1^{a_i}\lambda_2^{b_i}\lambda_3^{c_i}\mu_1^{d_i}\mu_2^{e_i}\mu_3^{f_i} \times \exp(-\alpha_1\lambda_1 - \alpha_2\lambda_2 - \alpha_3\lambda_3 + \beta_1\mu_1 + \beta_2\mu_2 + \beta_3\mu_3) S(p_i) + 2 \leftrightarrow 3]$$

where particle 1 is the positron, 2 and 3 are the electrons, λ_i and μ_i are prolate spheroidal coordinates for particle i, $a_i, \ldots, f_i$ are non-negative integers, $\alpha_1, \ldots, \beta_3$ are non-linear parameters and $2 \leftrightarrow 3$ indicates the corresponding exchange term. Depending on the value of p_i in $S(p_i)$, χ_i is a σ or π type CI function or a Hylleraas-type function. Both positron-electron and electron-electron correlation are taken into account.

The continuum wave function for the relative motion of the He and the $\bar{\mathrm{H}}$ was calculated using the BO potential of Strasburger et al. [3]. Very accurate or exact wave functions were used for the systems in the rearrangement channels. A description of this work at an earlier stage is given in ref. [4]. The latest results for the rearrangement cross sections for all three reactions will be reported at the conference.

In addition, a description will be given of a preliminary calculation on $\mathrm{H}_2 - \bar{\mathrm{H}}$ scattering [5].

[1] E.A.G. Armour and C.W. Chamberlain, J. Phys. B **35**, L47 (2002).

[2] S. Jonsell, A. Saenz, P. Froelich, B. Zygelman and A. Dalgarno, Phys. Rev. A **64**, 052712 (2001).

[3] K. Strasburger, H. Chojnacki and A. Sokołowska, J. Phys. B **38**, 3091 (2005).

[4] E.A.G. Armour, A.C. Todd, S. Jonsell, Y. Liu, M.R. Gregory and M. Plummer, Nucl. Inst. and Meth. B, in press (2007).

[5] M.R. Gregory and E.A.G. Armour, Nucl. Inst. and Meth. B, in press (2007).