Annihilation and rearrangement in atom-antihydrogen collisions

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Recently the ATHENA and ATRAP groups at CERN managed to produce antihydrogen atoms at low temperatures [1]. Future goals of these experiments are to trap the antihydrogen atoms and perform spectroscopic measurements comparing antihydrogen with ordinary hydrogen. Such measurements can test the CPT theorem for baryons and leptons.

The new experimental progress has also stimulated interest in low temperature atom-antiatom collisions. Such collisions have several properties that make them qualitatively very different from ordinary atom-atom collisions. One obvious difference is that in the Coulombic nucleus-antinucleus interaction is attractive. Hence, the nucleus and antinucleus have a finite probability of overlapping in an atom-antiatom collision. Therefore it is necessary to include the strong nuclear force between the nucleus and antinucleus. The strong nuclear force leads both to annihilation processes and to a change in the elastic cross section.

I will discuss how the strong nuclear force may be incorporated in calculations of low-energy antihydrogen-atom scattering. In particular I will discuss a scattering-length method, which has been applied to antihydrogen-hydrogen and antihydrogen-helium scattering [2, 3, 4].

Another important class of inelastic channels is rearrangement, in which the oppositely charged nuclei form a bound system, possibly also binding one or more of the electrons. The excess energy is carried off by the positron and the remaining electrons. In the case of low-temperature hydrogen-antihydrogen scattering, calculations show that rearrangement into positronium and protonium (the bound state of a proton and an antiproton) has a rate comparable to the rate for direct annihilation.

A difficulty in rearrangement calculations is the existence of a critical internuclear separation, below which the leptons are no longer bound to the nuclei. In particular I will focus on the antihydrogen-proton (or hydrogen-antiproton) system, which is the simplest system possessing a critical distance. For this system the critical distance $R_c = 0.639a_0$ was found as early as 1947 [5]. I will give a new analytical result for the binding energy of the electron/positron for $R \gtrsim R_c$. I will also show that the Born-Oppenheimer approximation breaks down as $R \to R_c$. This problem can be cured by explicitly including rearrangement channels through an optical potential [6]. I will present low-energy rearrangment cross sections calculated using this method.

References

[1] M. Amoretti *et al.*, Nature **419**, 456 (2002); G. Gabrielse *et al.*, Phys. Rev. Lett. **89**, 213401 (2002).

[2] S. Jonsell, P. Froelich, S. Eriksson and K. Strasburger, Phys. Rev. A **70**, 062708 (2004).

[3] S. Jonsell, A. Saenz, P. Froelich, B. Zygelman and A. Dalgarno, J. Phys. B **37**, 1195 (2004).

[4] S. Jonsell, A. Saenz, P. Froelich, B. Zygelman and A. Dalgarno , Canadian J. Phys. **83**, 435 (2005).

[5] E. Fermi and E. Teller, Phys. Rev. **72**, 399 (1947).

[6] B. Zygelman, A. Saenz, P. Froelich and S. Jonsell, Phys. Rev. A **69**, 042715 (2004).