Radiative recombination of an electron on two remote protons: oscillator strengths

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This is the first attempt to calculate the oscillator strengths relevant to free-bound radiative transitions encompassing three charged particles: an electron and two protons. In this process, a free electron collides with two protons, emits a photon, and generates the hydrogen molecular ion, H_2^+, in either ground or excited states (see Fig.1). These oscillator strengths are crucial for a spectrum of applications, spanning from controlled fusion research to the exploration of processes occurring in the early Universe.

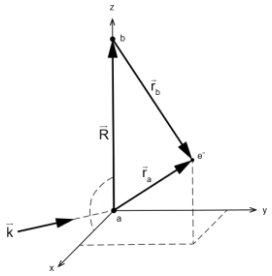

Fig. 1. Orientation of wavevector $\vec{k}$ concerning the molecular axis of H_2^+.

In this study, explicit expressions for the dipole strength matrix elements for free-bound radiative transitions at large distances R between protons have been derived. These matrix elements were obtained by expanding the discrete and continuum spectra wavefunctions in an inverse power of R. The two leading terms of all non-zero matrix elements are presented; the third term is cumbersome, and therefore, it is omitted.

The asymptotic technique leads to algebraic representation, contrasting with numerical tables. This method not only facilitates the avoidance of various numerical difficulties but also allows for the analytical calculation of the six-fold integral arising in the seven-fold integral of the developed calculation scheme. The bound state wavefunction for H_2^+ is derived in our early works. For the continuum state wavefunction, we employ the Coulomb-Bohr approximation.

The outcomes of the present analytical calculations, along with data on the oscillator strengths, will be detailed in an upcoming paper. The application of the obtained data is envisaged to address radiative issues in hydrogen plasmas and study various processes that occurred in the early Universe. We emphasize that the employed Coulomb-Born approximation with the CGF derived in parabolic coordinates is applicable for the calculation of the continuum spectrum wavefunction at the intermediate and small internuclear distances too. However, in such cases, the oscillator strengths will be obtained numerically.

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Reference

1. T. Kereselidze, I. Noselidze, and Z. Machavariani, (2024) (the paper is submitted to EPJD)