Collisional and transport processes of low-energy positrons in molecular hydrogen

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In this work we will give a brief review of positron physics, focusing on the astrophysical processes that positrons undergo in our Galaxy. Several important astrophysical objects are identified as sources of positrons and the physics of positron production and annihilation will be discussed. We discuss in which way the low-energy positron community could help to the positron astrophysics community to make further progress in understanding positron-matter interactions and the matter-antimatter asymmetry problem. As an example, we study the collisional and transport processes of positrons in H_2, which is one of the most abundant molecules in our Galaxy (Prantzos et al. 2011, Banković et al. 2012).

We apply a multi term theory for solving the Boltzmann equation and Monte Carlo simulation technique (Dujko et al. 2010) to investigate various aspects of positron transport in H_2 under the influence of electric and magnetic fields crossed at arbitrary angles. The hierarchy resulting from a spherical harmonic decomposition of the Boltzmann equation in the hydrodynamic regime is solved numerically by representing the speed dependence of the distribution function in terms of an expansion in generalized Laguerre polynomials about a Maxwellian velocity distribution at an internally determined temperature. Positron transport properties, including mean energy, drift velocity and diffusion tensor, are calculated over a range of reduced electric and magnetic fields, and angles between the fields. The rate coefficient for positronium (Ps) formation is also calculated and compared with other rate coefficients. It is found that the difference between the two sets of transport coefficients, the bulk, and the flux, resulting from the explicit effects of Ps formation, can be controlled either by the variation in the magnetic field strengths or by the angles between the fields. Special attention is given to the synergistic effects of Ps formation and angle between the fields on the phenomenon of negative differential conductivity (Banković et al. 2009). In addition, it is found that the off-diagonal elements of the diffusion tensor can have magnitudes of an equivalent order of the diagonal elements suggesting consideration is required for their inclusion into prospective models of positron traps.

Among many interesting phenomena we note the existence of runaway positrons in H_2. This raises a question: Is a set of cross sections for the scattering of positrons in H_2, used as input to solve the Boltzmann equation, complete? To resolve this issue and as a first step, we investigate the influence of rotational excitation on positron transport for the lower values of the applied electric fields. The cross sections for rotation excitations are calculated assuming the Gerjuoy-Stein and Dolgarno-Moffett theories (Natisin et al. 2014). As a curiosity, we note that in this work we present the variation of the third-order transport coefficients for positrons with the applied fields for the first time.

In the final segment of this work, we will discuss our Monte Carlo models of a Penning-Malmberg-Surko positron trap (Fajans and Surko, 2020). It will be shown that positrons begin to move from a beam-type distribution and thermalize to an isotropic Maxwellian distribution at a given temperature. Simulation results will be displayed for a range of trap settings, including those using mixtures of N_2 and CF_4, pure CF_4 and pure H_2. We will illustrate the high efficiency of a positron trap that uses pure CF_4 using advanced Monte Carlo modeling and physical arguments (Marjanović et al. 2016).

References

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