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ON DIFFUSION OF POSITRONS IN ELECTRIC AND MAGNETIC FIELDS IN MOLECULAR GASES

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Abstract. Diagonal elements of the diffusion tensor for positron swarms in molecular gases under the influence of electric and magnetic fields are investigated using a Monte Carlo simulation technique and multi-term theory for solving the Boltzmann equation. The focus was on the synergetic effects of non-conservative collisions and magnetic fields on the diffusion of positrons. It is found that different diagonal elements of the diffusion tensor show different sensitivities to the strength of magnetic field and on the presence of non-conservative collisions.

1. INTRODUCTION

The fundamental properties of positrons and their interactions with matter are the subject of growing interest (Charlton and Humberston 2000). Atomic physics, condensed matter physics, biomedical diagnostics and gamma-ray astronomy are among many areas where positrons have found applications. Until recently the progress in this field has been limited by the lack of sufficiently strong low-energy positron beams. The development of efficient positron traps (Surko et al. 1988) changed this situation and opened a possibility for measuring the cross sections for positron-matter interactions at very low energies with high accuracy. For the first time, the reasonably complete sets of cross sections which describe interactions between positrons and different atoms and molecules became available, which in turn enabled studies of positron transport in gases.

In our previous papers (Banković et al. 2008, 2009) the transport properties of positrons swarms in molecular gases have been presented. In this paper we focused on the diagonal elements of the diffusion tensor for positron swarms in H_2, N_2 and water vapour. If a swarm of positrons is drifting under the influence of electric field only, then the diffusion tensor has three non-zero diagonal elements: one longitudinal component and two transverse components which are by symmetry equal. In a crossed electric and magnetic field configuration there are five non-zero elements of the diffusion tensor. First, there are three diagonal diffusion elements along the **E** ($D_{\mathbf{E}}$), the **E**×**B** ($D_{\mathbf{E}\times\mathbf{B}}$), and **B** direction ($D_{\mathbf{B}}$), respectively. Second, there are also two individual off-diagonal elements which are not the same, but experimentally can not be individually measured. They form the so-called Hall diffusion coefficient and are responsible for the existence of the fluxes known as the Hall current which is experimentally detectable. In this work we investigate the influence of the non-conservative nature of the positronium (Ps) formation process on the diagonal elements of the diffusion tensor and also the effects induced by the presence of the magnetic field in a crossed field configuration. All results are obtained using a Monte Carlo simulation technique and multi-term theory for solving the Boltzmann equation.

2. POSITRON SWARM IN ELECTRIC FIELD

One of the most critical issues within the contemporary swarm studies is a distinction between the bulk and flux transport coefficients induced by non-conservative collisions. In the majority of the previous work in the plasma modelling community and related electron studies this distinction has been systematically ignored. Fig. 1a shows the bulk and flux longitudinal and transverse components of the diffusion tensor for positron swarm in H_2. The huge differences between the flux and bulk longitudinal components are clearly evident. Note that such huge differences have never been observed for electron swarms (Dujko 2009). The anisotropic nature of the diffusion tensor is also clearly evident and as for electrons, the difference between the longitudinal and transverse diffusion coefficients is induced by the energy dependence of the collisional frequency. For those values of E/N where the transverse component of the flux diffusion coefficient dominates the longitudinal component, the electric field accelerates positrons along the field direction. If the collision frequency is an increasing function of the energy, then the positrons at the front of the swarm have a higher probability of collision with H_2 molecules than those at the back which acts to reduce diffusion of positrons in the direction of the field – the electric anisotropy effect. Conversely, along the direction transverse to the field, there is no such asymmetry in the local average energy and the electric anisotropy effect is absent. In the narrow region of E/Ns, between 1 and 3 Td, the collision frequency is a decreasing function of energy and the longitudinal is greater than the transverse diffusion coefficient. Similar but not identical behaviour of the diffusion coefficients has been observed for positron swarms in water vapour. For N_2 the difference between the flux and bulk diffusion components is drastically less evident due to the different relative positions of the thresholds for electronic excitations and Ps formation.

In order to better understand the influence of non-conservative collisions on the diffusion, the Ps formation is treated as an inelastic process. In Fig. 1b the differences between the flux diffusion coefficients, calculated in two different manners with respect to the nature of Ps formation process is a clear sign of the implicit effects of Ps formation, i.e. the direct effects of Ps formation on the distribution function of the swarm.

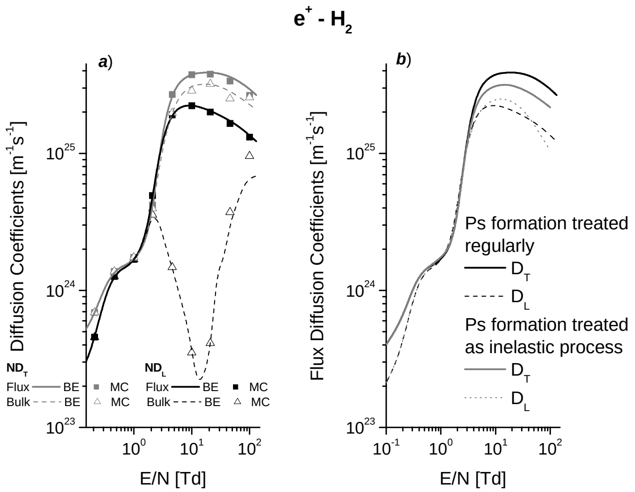

Figure 1: a) Diffusion coefficients for positron swarm in H_2 as functions of E/N; b) Transverse and longitudinal flux diffusion coefficients compared with the same coefficients calculated when Ps formation is treated as an inelastic process.

3. CROSSED FIELDS CONFIGURATION

In this section the synergetic effects of magnetic field and non-conservative collisions on the diagonal elements of the diffusion tensor are investigated. Generally speaking, it is hard to fully understand the behaviour of diffusion coefficients in electric and magnetic fields since many parallel factors affect them significantly. Among these factors are the effects of thermal anisotropy, magnetic anisotropy and electric anisotropy. In addition, the collisions and complex energy dependence of collision frequency further complicate this issue.

Different diagonal elements of the diffusion tensor show different sensitivities with respect to magnetic field, non-conservative collisions and generally to the energy dependence of the cross sections. The diffusion coefficients along the **E** and **E**×**B** directions can vary up to five orders of magnitude in the limit of low values of E/N where the magnetic field controls the behaviour of the swarm. The longitudinal diffusion coefficient shows the highest sensitivity with respect to the presence of Ps formation, i.e. differences between flux and bulk values are much higher for this diffusion coefficient than those observed for $D_{\mathbf{E}\times\mathbf{B}}$ and $D_{\mathbf{B}}$ components. In Fig. 2 the longitudinal diffusion coefficient for positron swarm in water vapour is displayed. $D_{\mathbf{B}}$ component shows the weakest sensitivity to the changes of magnetic field. Essentially, it follows the variation of the mean energy with both E/N and B/N, and hence the thermal effects play the most important role in the behaviour of this transport property. In conclusion, better understanding of the synergetic effects of the magnetic field and non-conservative collisions on the diffusion in **E** and **B** fields requires knowledge of the spatially resolved data, particularly those associated with the second order variations of the average energy along the swarm.

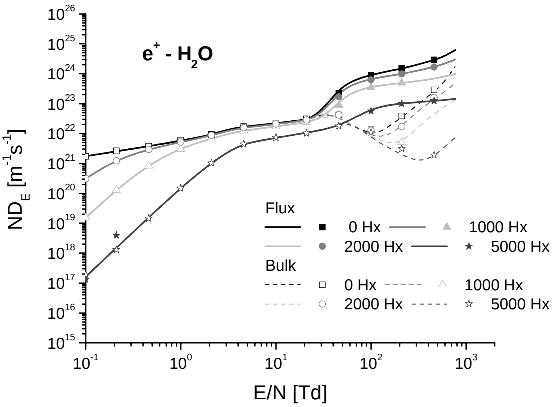

Figure 2: Longitudinal diffusion coefficient as a function of E/N for various B/N for positron swarm in water vapour.

Acknowledgements

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References

Bankovic, A., Marler, J. P., Šuvakov, M., Malovic, G., Petrovic, Z. Lj.: 2008, *NIMB,* **266**, 462.

Bankovic, A., Petrovic, Z. Lj., Robson, R. E., Marler, J. P., Dujko, S., Malovic, G.: 2009, *NIMB,* **267**, 350.

Charlton, M. and Humberston, J.: 2000, Positron Physics (New York: Cambridge University Press).

Dujko, S.: 2009, PhD Thesis, James Cook University, Townsville, Australia.

Surko, C. M., Passner, A., Leventhal, M., Wysoki, F. J.: 1988 *Phys. Rev. Lett.*, **61**, 1831.