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TRANSPORT COEFFICIENTS FOR POSITRON SWARMS IN MOLECULAR GASES

Ana Banković(1,*), Saša Dujko(1), Ronald D. White(2), Stephen J. Buckman(3), Gordana N. Malović(1), Joan P. Marler(4) and Zoran Lj. Petrović(1)

(1) Institute of Physics, University of Belgrade, Pregrevica 118, POB 68, Zemun, Serbia

(2) ARC Centre for Antimatter-Matter Studies, School of Engineering and Physical Sciences, James Cook University, Townsville 4810, Australia

(3) ARC Centre for Antimatter-Matter Studies, The Australian National University, Canberra, ACT, 0200, Australia

(4) Northwestern University, Evanston, IL, USA

(*) **ana.bankovic@gmail.com**

Transport of positrons in various environments is interesting from many points of view [1]. They are standing behind the origin of astrophysical sources of annihilation radiation; they play a crucial role in production and detection of cold anti-hydrogen and also in the production of positronium (Ps). Recent investigations of positrons have triggered a whole new interesting research area – ionized gases with positrons that may be analyzed using similar techniques albeit for their short lifetime and even the antimatter plasmas. In addition, positrons have been already used for characterization of materials. However, perhaps the most important applications of positrons from the viewpoint of transport studies are the positron buffer-gas traps, such as the Surko trap, and also the use of positrons in the medical diagnostics of positron emission tomography (PET) and possible cancer treatments. Thanks to the recent advances in experimental measurements of high-resolution, low-energy inelastic positron scattering cross sections [2], the determination of positron transport coefficients over a wide range of energies has become possible. These measurements confirm that Ps formation, a non-conservative process unique to positrons, has a much larger cross section than annihilation and the analogous loss process for electrons- the dissociative attachment. This fact, coupled with a very strong energy dependence for Ps formation, is expected to lead to kinetic effects [3].

Calculations of transport properties have been performed for positrons in molecular hydrogen, nitrogen and water vapour in varying configurations of electric and magnetic fields. This work is the extension of the previous work on positron transport in noble gases [4]. Both hydrogen and nitrogen have been used as buffer gases in positron traps [5] and this study reveals why the latter is the better choice. On the other hand, interest in water molecules is based on their great biological importance. From our experience, the best way to study the transport phenomena of positrons theoretically is based on a methodology of combined Monte Carlo simulations and calculations based on a multi-term theory for solving the Boltzmann equation. The former technique is suitable under conditions when large gradients in positron density induce drastic modification of the usual Gaussian profile associated with the pronounced spatial differentiation of the positrons by energy [4]. The latter is more suitable under conditions of strong magnetic fields where the intensive gyration of positrons dramatically limits the computational efficiency of Monte Carlo simulation.

In this work we investigate the influence of Ps formation on the positron transport properties. For hydrogen and water the Ps formation channel opens before electronic excitations and its effects on the behavior of the swarm are dramatic. The bulk and flux drift velocities (see Fig. 1.) may be orders of magnitude different and then negative differential conductivity (NDC) occurs only in the bulk component. In the case of nitrogen such effects have not been observed. This follows from the fact that for nitrogen the electronic excitations have lower thresholds compared to those for the Ps formation. This is the reason why nitrogen is a much better choice for a buffer gas in positron traps, although thermalization of positrons in hydrogen occurs much faster [6]. The impact of the magnetic field in a crossed field (**E×B**) configuration is also examined. For all gases considered in this work, the magnetic field lowers the mean energy of the positron swarm. This is the well-known magnetic cooling effect, previously observed many times for electrons [7]. It is interesting to note that for hydrogen and water the application of the magnetic field first diminishes and then removes the NDC from the profiles of the drift speed although it is strongly present in the axial component of the drift velocity. Similar but not identical effects have been observed for argon [8].

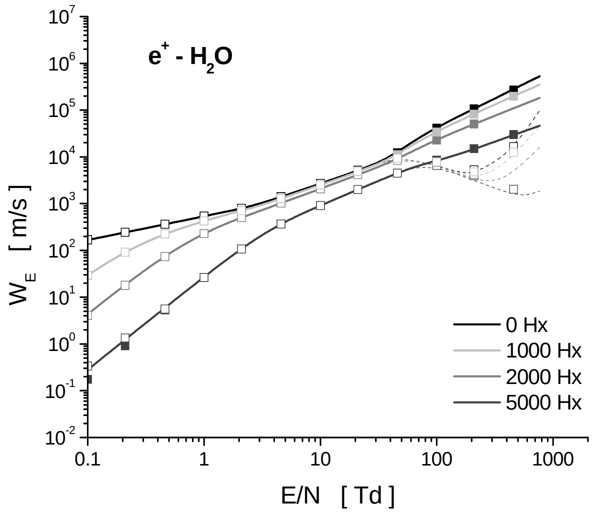

Fig. 1: Variation of the longitudinal drift velocity component with E/N for a range of applied magnetic fields. Results obtained by a multi-term theory for solving the Boltzmann equation (full line flux, dashed line bulk) are compared with those obtained by a Monte Carlo simulation technique (full symbols flux, open symbols bulk).

References

[1] Charlton M and Humberston J 2000 Positron Physics (New York: Cambridge University Press)
[2] J. P. Sullivan, S. J. Gilbert, J. P. Marler, R. G. Graves, S. J. Buckman, C. M. Surko 2002 *Phys Rev. A* **66** 042708
[3] R. Robson, R. White, Z. Lj. Petrović 2005 *Rev. Mod. Phys.* **77** 1303
[4] M. Suvakov, Z. Lj. Petrović, J. P. Marler, S. J. Buckman, R. E. Robson, G. Malović 2008 *New J. Phys.* **10** 053034
[5] C. M. Surko, R.G. Greaves 2004 *Physics of Plasmas* **11** 2333
[6] I. Al-Qaradawi, M. Charlton, I. Borozan, R. Whitehead 2000 *J. Phys. B: At. Mol. Opt. Phys.* **33** 2725
[7] K. F. Ness 1994 *J. Phys. D: Appl. Phys.* **27** 1848
[8] J. P. Marler, Z. Lj. Petrović, A. Banković, S. Dujko, M. Šuvakov, G. Malović, S. J. Buckman 2009 *Physics of Plasmas* **16** 057101