Experimental Study of Momentum-transfer Cross Section and $^1Z_{eff}$ for Slow Positronium-Gas Collisions

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It is possible to extract useful quantitative information on Positronium (Ps) interactions at lower energies using the angular correlation of annihilation radiation (ACAR) method combined with the use of silica aerogel. The material has also been employed in the studies of ortho-positronium (o-Ps) through lifetime technique. The silica aerogel is a three-dimensional network composed of silica grains. Since the free space between the grains is connected to the outer space, the gas atoms or molecules to be investigated can diffuse immediately into the inner space. When positrons from a radioactive source are injected into this material, about half of the positrons form Ps atoms in the grains or on the surface of the grains. The Ps atoms are emitted into the free space due to the negative work function for SiO_2 with an emission energy of about 0.8 eV. The Ps atoms then interact with the atoms/molecules in the space and with the grain surfaces.

The momentum-transfer cross sections for positronium (Ps)-gas scattering in the low energy region have been obtained by using the one-dimensional angular correlation of annihilation radiation (1D-ACAR) method; the momentum distributions of Ps in the gases are measured as functions of mean lifetime of Ps varied by applying a magnetic field. The average energy obtained for o-Ps with mean lifetimes of 3 to 90ns is analyzed assuming that the Ps is thermalized by elastic scattering with gas atoms/molecules. In the low energy region, Ps is actually thermalized mainly through elastic scattering with diatomic and polyatomic molecules as well as inert gases.

The parameter characterizing the pickoff annihilation rate of Ps, $^1Z_{eff}$, is also studied using silica aerogel. Iwata et al. has reported a large increase in the parameter Z_{eff} characterizing positron annihilation in gases, suggesting formation of resonances or bound states in large molecules. It is thus worth performing a systematic study for the Ps annihilation counterpart. Our study has revealed that $^1Z_{eff}$ increases linearly with the molecular polarizability with a somewhat exceptional behavior of Xe. A good correlation is also found with the geometrical cross section of the molecule. This indicates that the Ps pickoff annihilation takes place without forming a resonance or a bound state.

Discrimination of spin conversion (ortho-para conversion) and pickoff conversion of Ps in sxygen will also be reported.