Investigations of Positronium Formation and Destruction using PsARS*

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The development of positronium annihilation ratio spectroscopy (PsARS) has been found to be particularly useful for investigations of positronium formation and destruction [1]. This new method of spectroscopy relies on measuring the relative ratio of γ-rays resulting from the annihilation of ortho-Ps to those from the annihilation of para-Ps. Two NaI scintillators with attached phototubes on opposite sides of a positron beam transmission scattering cell are used to detect in coincidence the two 511 keV γ-rays from para-Ps decay and to also detect in coincidence 2 of the 3 γ-rays (in the energy window 300 to 460 keV and completely excluding the 511 keV peak) from ortho-Ps decay.

It has been found [1] that within 2 eV of the initial Ps formation threshold for many target gases that the ratio ($R_{3\gamma/2\gamma}$) of the 2 of 3 γ-ray signal from ortho-Ps decay to that of the 2 γ-ray signal from para-Ps decay remains nearly constant and then decreases rapidly indicating that ortho-Ps has a formation potential (i.e., like a work function except that Ps cannot exist within metals) of about 2 eV with respect to the aluminum scattering cell surface and consistent with a value deduced [2] for a "clean" aluminum surface. If ortho-Ps has a kinetic energy above 2 eV it breaks up at the surface and greatly increases the likelihood that the resulting positron will annihilate via two 511 keV γ-rays. Comparing the $R_{3\gamma/2\gamma}$'s obtained for O_2 and CO_2 with the $R_{3\gamma/2\gamma}$ for Ar versus positron energy above the Ps formation threshold provides evidence for Ps formation with inner orbital electrons [1]. The binding energies of the outermost inner orbital electrons deduced from these PsARS measurements are consistent with those determined by photoelectron spectroscopy. A most recent analysis indicates that a significant fraction (from 20 to 35%) of the Ps formed a few eV above the threshold for forming Ps with the outermost inner orbital electrons of O_2 and CO_2 is due to these inner orbital electrons. Several other PsARS investigations will be discussed, including the anomalous measured $R_{3\gamma/2\gamma}$ values at the Ps threshold for N_2 suggesting a possible attachment of the incident positron to N_2, and studies with different scattering cell surfaces and target gases.

*This research is supported by the National Science Foundation.

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