

NEW RESULTS ON POSITRON-MOLECULE ANNIHILATION, VIBRATIONAL FESHBACH RESONANCES AND BOUND STATES

Jason A. Young*

Department of Physics, University of California San Diego, USA

Positron trapping techniques have improved over the years allowing many scattering experiments that were previously not possible. One such advance is the use of a Penning-Malmberg buffer-gas trap and a solid rare-gas moderator to produce pulses of cold, monoenergetic positrons (~ 25 meV, FWHM). This cold beam was used to measure the first energy-resolved positron-on-molecule annihilation spectra [1,2]. Strong peaks in annihilation rate are observed at energies just below the vibrational modes of various molecules, such as alkanes (C_nH_{2n+2}). These peaks are due to vibrational Feshbach resonances (VFR) and provide evidence of positron-molecule binding.

It is presently unclear as to how various molecular features relate to positron-molecule binding and the magnitude of observed resonances in annihilation rate. To complicate matters, it seems that there are both global factors, which relate to all modes, and local factors, which relate to individual modes. For example, substitution of a single fluorine atom for a hydrogen in a large alkane reduces significantly the annihilation peaks associated with much of the vibrational mode spectrum, while the modes themselves are only marginally different [2]. We describe here the results of new experiments designed to further understand the global and local factors that determine positron-molecule binding and the annihilation resonances.

In this paper, the dependence on target morphology is studied for the ring hydrocarbons benzene, cyclohexane and cyclopropane. The spectra for these molecules are compared with those for alkanes (i.e., which are linear). Intriguing features of each comparison will be discussed. Results for halogenated methanes will also be discussed.

Since evidence indicates that the positron resonances are closely linked to the spectrum of vibrations, it is worth investigating the relative contribution of each type of mode to these resonances. Energy resolution limits our ability to distinguish between some modes in a single molecule, and so we examine collections of molecules which possess similar modes (e.g., ring molecules and halogenated methane molecules) in order to identify the modes responsible for VFR.

Also of interest is the extent to which simple, long-range electrostatic coupling can explain the magnitudes of the observed VFR. To address this, a comparison is presented of the annihilation and infrared-absorption spectra for various molecules. While some features in the IR and annihilation spectra are similar, it appears that this coupling alone cannot account for the observed annihilation spectra.

Finally, evidence is presented for a second, "positronically excited" bound state in the largest alkane molecules studied ($C_{12}H_{26}$, and $C_{14}H_{30}$). For these molecules, a second annihilation peak is observed slightly downshifted from the position of the C-H stretch mode. The energy at which this feature occurs is lower in the larger molecule, consistent with the previously observed result that the positron binding energy increases with molecular size.

This work is supported by NSF grant PHY 02-44653.

*In collaboration with L. D. Barnes, and C. M. Surko.

- [1] S. J. Gilbert, *et al.*, *Phys. Rev. Lett.*, **88**, 043201 (2002).
- [2] L. D. Barnes, *et al.*, *Phys. Rev. A*, **67**, 032706 (2003).