Ortho-paraconversion of positronium in a dielectric with metallic inclusions

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A new mechanism was experimentally established for the ortho-paraconversion of positronium localized in a dielectric matrix near the surface of a metallic particle.

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Inasmuch as the work function of an electron from a metal is smaller than the positronium binding energy ($\phi < 6.8$ eV), it follows that even thermalized positrons can form positronium in the ground state on a metal surface. To observe this experimentally it is necessary that the positrons be stopped near the surface of the metal. In[1], a highly dispersed metal included in a dielectric zeolite matrix was used for this purpose. On the surface of a bulky sample of metal, the most effective positronium formation (~ 85%) was observed for positrons with initial energy of about 10 eV.[2]

In this study we have established experimentally the previously predicted[3] effect of ortho-paraconversion of positronium near a metal-dielectric interface.

In a dielectric with metallic inclusions, the produced positronium can be localized near a metallic surface, a fact that stimulates its ortho-paraconversion via ex-

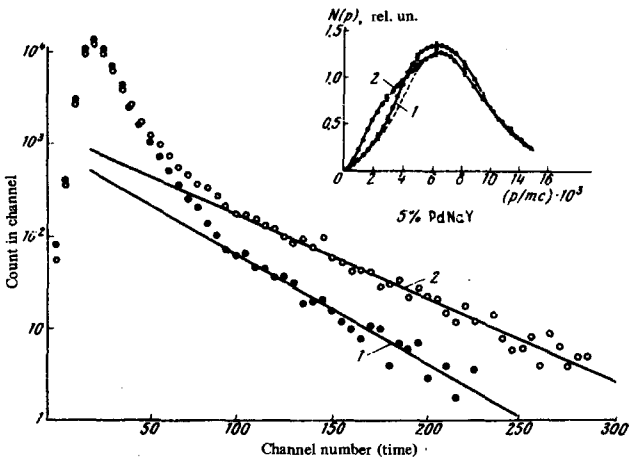

FIG. 1. Temporal spectra and momentum distributions of the annihilating e^+e^- pairs in the palladium-zeolite system: 1—cation form of palladium; $\tau_2 = 1.6$ nsec, $I_2 = 5.5\%$ (±5%), 2—metallic form of palladium, $\tau_2 = 2.0$ nsec, $I_2 = 16\%$ (±5%), $I_N = 9.5 \pm 1\%$.

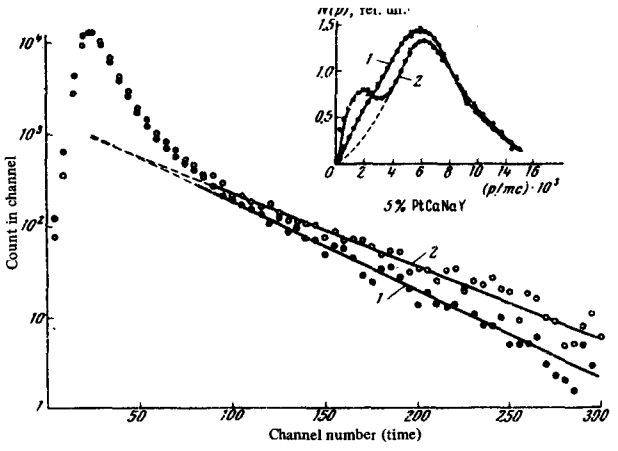

FIG. 2. Temporal spectra and momentum distributions of annihilating e^+e^- pairs in the platinum-zeolite system: 1) cation form of platinum, $\tau_2 = 2$ nsec, $I_2 = 15\%$ (±5%); 2) metallic form of platinum, $\tau_2 = 2.4$ nsec, $I_2 = 17\%$ (±5%), $I_N = 12.5 \pm 1\%$.

change with the metal electrons near the Fermi surface. Estimates of the effectiveness of this process, given in[3], show that manifestations of the positronium conversion should be expected when the positronium is localized in voids of diameter on the order of 10 Å that border on the metallic phase. The obtained estimates stimulated a search for a new mechanism of ortho-para-conversion of positronium near a metal surface. The first results of an experimental study of this question are presented below.

The temporal and correlation (angular) measurements were performed with samples of zeolite (Ca)NaY ($SiO_2/Al_2O_3 = 4.5$–6.0) containing 5 wt.% palladium and platinum. The samples were prepared by a method described earlier.[1] In contrast to[1], the samples were pellets obtained from the corresponding polycrystalline powders at a pressure of 2000 kg/cm². According to x-ray structure analysis (broadening of the diffraction peak), the average dimension of the palladium crystal in the sample with the reduced metal was approximately 60 Å as against 240 Å for the platinum.

The temporal spectra were obtained with apparatus having an approximate resolution 0.3 nsec. Measurements of the angular correlation of the annihilation γ quanta were carried out in a slit geometry using apparatus with a resolution 0.78 mrad. The momentum distributions of the annihilating e^+e^- pairs, with allowance for the apparatus function of the setup by the method proposed in[4], were obtained by solving the integral equation

$$f(\theta) = \int_0^\infty N(p) \left\{ \int_{-p}^{p} R(\theta' - \theta) (d\theta'/p) \right\} dp \qquad (1)$$

by the statistical regularization method which was applied to this problem in[5]. The following notation is used in Eq. (1): $f(\theta)$ is the experimental angular distribution, $N(p)$ is the sought momentum distribution, $R(\theta' - \theta)$ is the apparatus function of the installation.

The results of the temporal and angular measurements are shown in Figs. 1 and 2. A comparison of $I(N)$ (parapositronium) and I_2 (orthopositronium) for metal-containing zeolite samples shows that the ratio $3I_N/I_2$ is double the value corresponding to the statistical weights of the para and ortho states of positronium, thus indicating a high efficiency of ortho-paraconversion of these systems. Estimates of this ratio for the cation forms of palladium and platinum in zeolite show that it has the normal value ($3I_N/I_2 \approx 1$) within the limits of the experimental errors. All this allows us to ascribe the ortho-paraconversion of positronium in metal-containing samples to the aforementioned mechanism near the metal-dielectric interface.[3]

In systems with highly dispersed metal, size effects are possible in principle in the formation and ortho-paraconversion of positronium, since the work function of the electrons increases noticeably for sufficiently shallow metallic particles[6] and the electron-excitation spectrum may become discrete.[7] However, the conditions of the experiments and their accuracy do not make it possible to use the results to draw definite conclusions concerning size effects.

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