Attempt to Detect the Lyman α Line of the Positronium Atomic Spectrum*

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An unsuccessful attempt to observe the 2430-A Lyman α line of the positronium atom is described. The construction of the source was based on the assumption that occasionally a slow positron at the surface of a metal will capture an electron to form an excited positronium atom which will emerge and radiate.

HEREIN is reported an unsuccessful attempt to observe the Lyman α line of the positronium atomic spectrum (2430 A, calculated). The experiment is related to recent research concerned with the behavior of positrons in solids.

We assumed that when positrons, passing through a solid, have their energies reduced to $\sim$5 ev near the surface, an appreciable fraction will capture negatrons to form positronium atoms, some in excited states, and, passing through the surface, provide immediately outside a source of atomic positronium radiation. The results of Madansky and Rasetti[1] and the discussion of Garwin[2] lend support to this suggestion. The following arguments were also proposed: Once formed, the positronium atom in the solid should be rather stable against ionization even if (as in excited states) its binding energy is small, for the ionization process will be impeded by the lack of empty states available for the negatron; the process requires enough energy to raise the negatron essentially to the top level of the Fermi sea. The positronium atom has the property (unique among atoms) of zero charge density (apart from perturbation); this will result in a small collision cross section, and hence a large mean-free-path, a low rate of energy loss (the initial energy is expected to be $\sim$5 ev), and a small surface barrier. The measurements of Hall[3] and the calculations of Jackson and Schiff[4] on the behavior of protons of comparable velocities at a metallic surface give some support to the proposal. With no detailed analysis, a mean diffusion length for positronium atoms in gold of 4×10^{-5} cm was assumed; this is ten times the mean diffusion length for positrons estimated by Madansky and Rasetti.[1] It was assumed that, of the atoms escaping through the surface, 10% would be in excited states leading to the Lyman α line. Applied to the experimental setup, these assumptions led to an expected intensity 60 times as great as the minimum detectable signal.

The spectrometer included two aluminized paraboloidal mirrors and a 3×4 inch 60° NaCl prism. The detector was a 1P28 photomultiplier, cooled by liquid nitrogen. The source, spectrometer components and detector were enclosed in a single vacuum chamber. For the typical geometry (entrance slit $0.011\times\frac{3}{8}$ inch, detector slit $0.033\times\frac{3}{8}$ inch), the transmission (at 2430 A) was 0.1% and the resolving power ($\lambda/\delta\lambda$) was 110. The detector was operated to count individual photoelectrons. In view of the background with source removed, the minimum detectable signal for a 10-minute run was computed to be 1.7 counts/min. Estimations of the characteristics of the detector indicated that this counting rate would correspond to 0.6 photon/sec (at 2430 A) incident on the detector slit. The operation of the photomultiplier will be described elsewhere.

One type of source was formed of gold foil 0.0015 inch thick bent into a hemicylinder of radius 0.02 inch and length 0.375 inch. Cu^{61}, produced by the University of Washington cyclotron, was electroplated (carrier-free) on the convex side; positron activities of 90 mC (measured with a scintillation spectrometer telescope) were used. The atomic radiation was expected to emanate from the space between the concave surface of the source and the spectrometer slit a short distance ahead of it. A magnetic field of 8000 gauss increased the yield of the source by returning many slow positrons to the foil. Radiation from the source produced a counting rate of 50 counts/min above the background, but with a roughly uniform spectral distribution, in the region 2350–2650 A. There was no apparent indication that this radiation was associated with the formation of positronium. It was demonstrated that these counts were not the response of gamma or x radiation transmitted from the source to the detector directly.

The experiment was repeated with a source modified by the addition of a coating of polystyrene $\sim$0.001 inch thick deposited on the concave surface, and again with a source modified by the insertion of a fused quartz rod inside the hemicylinder. In these instances intense fluorescence of the transparent materials prohibited the search for the positronium line. Very similar spectra were obtained when such sources were excited by negatrons from Au^{198} produced by neutron irradiation of the gold foil.[5]

The definitely negative result with the simple gold foil source indicated some error in our conception of the phenomena involved.

* R. L. Brock, Ph.D. thesis, University of Washington, 1955 (unpublished).

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[1] L. Madansky and F. Rasetti, Phys. Rev. **79**, 397 (1950).

[2] R. L. Garwin, Phys. Rev. **91**, 1571 (1953).

[3] T. Hall, Phys. Rev. **79**, 504 (1950).

[4] J. D. Jackson and H. Schiff, Phys. Rev. **89**, 359 (1953).

[5] Pile irradiation performed by the Oak Ridge National Laboratory, Oak Ridge, Tennessee.