CHINESE JOURNAL OF PHYSICS VOL. 5 NO. 1 APRIL, 1967

Annihilation of Positrons in Aluminum, Rhodium and Silver

TUAN-WU CHEN (陳端梧), ING-JIUNN MA (馬英俊) and
JI-PENG CHIEN (錢積彭)

National Tsing Hua University, Taiwan, China

(Received March 28, 1967)

To study the annihilation of positrons in solids provides a mean for the investigation of the dynamic behaviours of electrons. The angular distribution of annihilated gamma-rays is related to the liner momentum distribution of the participating electrons. However, interpretation of the experimental results is made difficult by the lack of a precise understanding of the angular distribution curve(1). For metals, if the Fermi gas model applies, it is relevant to determine the unit electron sphere radius and the Fermi momentum of the electron from the experimental results of the angular distribution of the annihilated gamma-rays. The unit electron sphere radius, r, can be written as(2)

$$r=a_0r_s=(3/4\pi)^{1/3}(A/NZ\rho)^{1/3} \tag{1}$$

and the Fermi momentum is

$$P_F=\hbar k_F=1.917/a_0r_s \tag{2}$$

where, a_0 is the first Bohr radius, N is the Avogadro's number, A is the atomic number of the element with valence Z and density ρ. r_s is a dimensionless parameter and can be written as

$$r_s=13.99/\theta_c,\ (\theta_c \text{ in milliradians}). \tag{3}$$

θ_c is the "cut-off" angle of the angular distribution and can be determined experimentally.

The experimental set-up included a double coincidence circuit with a resolution of $\sim 1\mu$ sec. Two pieces of NaI(Tl) crystals, 3 inches in diameter and 3 inches in height, coupled to photomultipliers were used as gamma-ray detectors. Na^{22} was used as the positron source and made in a sandwich type, the meat being as the sample. The source and the sample were positioned at the center of a rack and was shielded so that the detectors saw only the sample, not the Na^{22} source. The source strength was $17\mu c$. The sample thickness was about twice the range of 0.54 Mev positrons. Both gamma detectors with slits of seperation 2 mm were placed face-tc-face opposite each other on the circumference of a two-meter-diameter circle with the sample as the center. One detector was fixed and the other was movable in 1 mm steps along the circumference. In order to reduce the chance coincidence, each detector was followed by a single channel analyzer to select the 0.51 Mev annihilated gamma rays. The results of the angular distributions are shown in Figure 1. At smaller angles, the angular distribution curves are inverted parabolas as predicated by theory. The coincidence counts at larger angles are believed due to the. annihilations with inner-shell or core electrons. Table 1 shows the results obtained from the experiment and compared with theory.

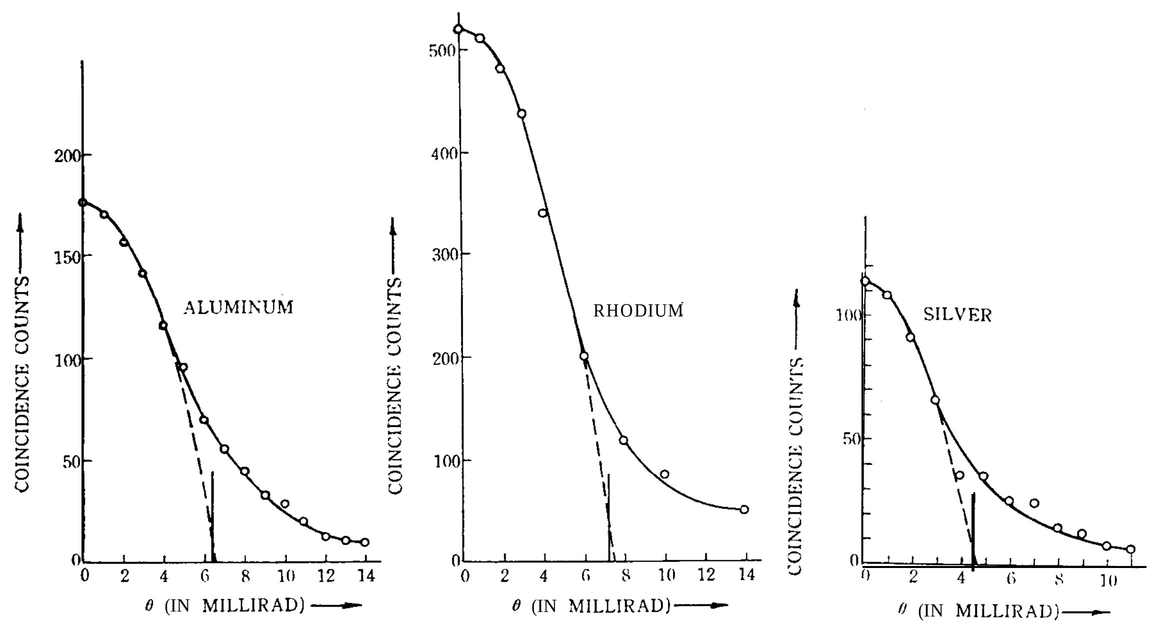

Fig. 1. Angular Distributions Annihilated Gamma-Rays in Aluminum, Rhodium and Silver

Table 1. Experimental results compared with theory

Sample	Z	θ_c (Millirad)		r (Bohr radius)		P_F ($\times 10^{-20}$ erg sec cm^{-1})		E_F (ev)	
		Theory	Exp.	Theory	Exp.	Theory	Exp.	Theory	Exp.
Al	3	6.75	6.4	2.07	2.18	18.4	17.5	11.6	10.8
Rh	3	7.21	7.1	1.94	1.97	19.6	19.4	13.1	13.0
Ag	1	4.66	4.5	3.0	3.10	12.7	12.3	5.54	5.15

(1) P. H. Wallace, *Solid State Physics*, Vol. 10, Academic Press. (1960)
(2) R. A. Ferrell, Revs. Modern Phys. 28, 308 (1956)