LETTERE ALLA REDAZIONE

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B

Fermi Energy and Doppler-Broadened Annihilation Radiation.

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(ricevuto il 5 Agosto 1968)

The Doppler broadening of the annihilation radiation has been demonstrated quite some time ago by DUMOND *et al.* (1) with a curved-crystal spectrometer and more recently by MURRAY (2) and HURLEY (3) using a high-resolution Ge(Li) detector. While the electron momentum distribution in the sample in which the positrons annihilate can be deduced only from a detailed analysis (3) of the entire Doppler-broadened annihilation, nevertheless, certain gross features of the annihilation process should be discernible from the width. One such feature is the Fermi energy.

We have investigated the Doppler broadening in the following materials: Cu, Al, Pb, Fe, Ni, Sb, Gd, Bi and Zn. The apparatus consisted of an ORTEC Ge(Li) detector ($5\ \text{cm}^2$ area; 4 mm depth) which has a resolution of 2.7 keV for the 514 keV line of ^{85}Sr used for obtaining the instrumental linewidth. The output of the FET preamplifier coupled to the detector was fed to a Canberra spectroscopy amplifier (Model 1417) and then to a biased amplifier (Canberra Model 860). The output of this was analysed by a Victoreen 400-channel analyser.

The positron source consisting of a ten μC ^{22}Na activity deposited at the centre of a $\frac{1}{2}$ cm diameter mylar foil ($\frac{1}{4}$ mil thick) was sandwiched between two pieces of a given specimen and placed 4 cm from the front face of the detector. The counting time for each sample was approximately 20 minutes and data for all samples were taken on the same day.

There were approximately 8000 counts in the peak of each spectrum and the same geometry was maintained for each sample. Although no stabilizer was used the drift was less than 2 channels over a period of 6 hours which characterized a typical run.

From our data we have computed the quantity x in keV, where

$$x = [\sigma^2 - \sigma_0^2]^{\frac{1}{2}},$$

(1) J. W. M. DUMOND, D. A. LIND and B. B. WATSON: *Phys. Rev.*, **75**, 1226 (1949).

(2) G. MURRAY: *Phys. Lett.*, **24** B, 268 (1967).

(3) H. P. HOTZ, J. M. MATHIESEN and J. P. HURLEY: *Phys. Rev.*, **170**, 351 (1968), and references cited therein.

where

σ = full width at half maximum of the Doppler-broadened spectrum for a given specimen (FWHM) and

σ_0 = FWHM for the 514 keV line of ^{85}Sr .

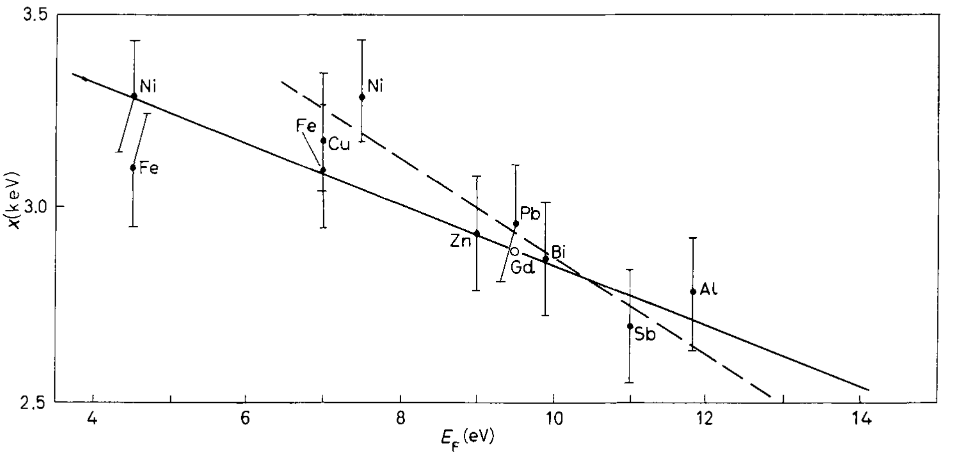

Fig. 1. – Plot of Doppler broadening x in keV (see text for definition) *vs.* Fermi energy in eV. Note that two sets of values for Ni and Fe are indicated and two corresponding lines are drawn. From our plot we compute for Gd a Fermi energy of (9.5 ± 1.5) eV.

In Fig. 1 we have plotted x in keV as a function of the Fermi energy in eV. Most of the Fermi energies were obtained from the review of Wallace (4). For Bi assuming 5 electrons/atom the value was calculated using the free-electron model. A linear plot is obtained, the width x decreasing with Fermi energy. From the measured value of x for Gd(= 2.89) we compute a Fermi energy of 9.5 ± 1.5 which compares favorably with the free-electron value of 7.5 assuming 3 electrons per atom.

What is indeed surprising is the *decrease* in the width as a function of Fermi energy. If the positrons sampled only electrons near the Fermi surface one would expect an *increase* in the width with Fermi energy. Our result would then suggest the interpretation that the positrons sample the entire Fermi sea rather than just the surface. A second possibility is the contribution of the core to the observed annihilations. Even if these two possibilities existed what causes a linear correlation is not clear to us.

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We are thankful to the Sigma Xi Foundation for financing the purchase of the source.

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(4) P. R. WALLACE: in *Solid State Physics*, Ed. F. SEITZ and D. TURNBULL (New York, 1960), p. 1.