by only one configuration of the vectors s, l, and I and therefore cannot yield information on the strength of spin-orbit coupling. The solid curve drawn in Fig. 1 is calculated from formula (1) taking $\sigma_{\text{potential}}=1.1$ barns, $(E_r)_{\text{lab}}=256$ kev, $J=3$, $l=1$, and $(\Gamma_n)_{\text{lab}}=40$ kev. In computing the curve, the variation of $\lambda\!\!\!^{-}$ and Γ_n with energy was taken into account. It is seen that the asymmetry of the resonance is nicely accounted for by the variation with energy of these two quantities. The dashed curve shows the behavior of the calculated curve away from resonance (fitted at resonance) for the assignment $J=3$ but $l=2$.

An almost coincident resonance ($E_n=270$ kev) has been reported for the $Li^6(n, \alpha)$ reaction.[3] If, by chance, there were a large coincident resonance in the σ_T of Li^6, calculations indicate that its maximum value could not exceed ~10 barns. When multiplied by the relative abundance of Li^6 (7.5 percent) it would contribute, at most, 0.75 barn to the σ_T of lithium at the peak of the resonance. The presence of such a resonance would, therefore, tend to improve the agreement of the calculated and experimental curves.

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On the Nature of the Superconducting State*

LASZLO TISZA
Department of Physics and Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts
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IN a recent paper[1] the author advanced the view that the discussion of superconductivity requires the use of many-electron wave functions. The superconducting transition was considered to be somewhat similar to an order-disorder transformation, with a characteristic difference. Instead of being frozen in a definite position in the crystal, the superlattice describing the ordered state is supposed to resonate, say, among ω-positions equivalent under the translation group of the crystal. An external electric or magnetic field would induce a supercurrent provided $\omega\geqq 3$. The case $\omega=2$ corresponds to an insulating state.

The superlattice itself was attributed to the electronic distribution alone; in other words the vibrations of the ions around the ideal lattice positions were ignored. However, recent experimental[2] and theoretical work[3] has provided convincing evidence that the interaction of the electrons with the lattice vibrations constitutes an essential aspect of superconductivity. Therefore, the study of the many-electron eigenfunctions has been reopened from a more systematic point of view. A detailed paper is now completed for publication, the results of which may be summed up as follows.

Fundamentally a crystal is a collection of electrons and nuclei. The usual separation of the electronic and vibrational wave functions is based on the adiabatic approximation.[4] One solves the electronic eigenvalue problem for fixed nuclear positions, and the electronic energy provides the potential for the nuclear vibrations. The validity of this method depends on the assumption that the electronic level is nondegenerate and its separation from the next one is large compared to the spacing of the nuclear states. This condition is not satisfied for the case of metals; hence a rigorous quantitative theory will have to overcome unusual difficulties.

We have applied symmetry considerations to obtain a qualitative insight into the possible coupling cases. The usual method of considering the metal as a mixture of an electron gas and a phonon gas appears only as one limiting case. This state may become unstable, resulting in a phase transition into a state exhibiting a resonating superstructure. This has the same symmetry properties as the superstructure postulated in reference 1 and could be used in a similar fashion to explain superconductivity and the well-known increase of the resistivity of certain metals at low temperatures. On the other hand, the dynamic properties of the superstructure are essentially different from those considered earlier. The superstructure is produced by the interlocking of the electronic and nuclear fluctuations; the coupling is so strong that it is no longer possible to consider the nuclear vibration as occurring in a fixed potential.

The present ideas are compatible with the Fröhlich-Bardeen conception[3] of the nature of the interaction responsible for superconductivity. However, the latter theories lead only to a short-range order, whereas we were able to define a parameter of long-range order marking the emergence of the above-mentioned superstructure.

The correspondence between the experimental facts and the theoretical possibilities provided by the symmetry consideration is suggestive. The conclusions obtained can be submitted also to a severe experimental test. Our postulated superlattice should give rise to x-ray superstructure lines. Existing x-ray investigations[5] are scanty and were carried out in view of finding variations in the lattice constant. Hence an x-ray study of the superconducting transition would be of considerable interest.

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A Search for Charge-Exchange Scattering of π^+ Mesons*

RICHARD WILSON† AND JOHN P. PERRY
University of Rochester, Rochester, New York
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EXPERIMENTS with photographic plates[1,2] showed meson tracks which stopped without any apparent nuclear interaction. These could be attributed to charge-exchange scattering events or to stars where only fast neutrons were emitted. Moreover, charge-exchange scattering need not always lead to events of this type, for some of the scatterings might be inelastic and give rise to proton recoils.

We have made a direct search for charge-exchange scattering of 44-Mev π^+ mesons on Be and D_2O. The experimental arrangement is shown in Fig. 1. The scintillation crystals 1, 2, and 3 count

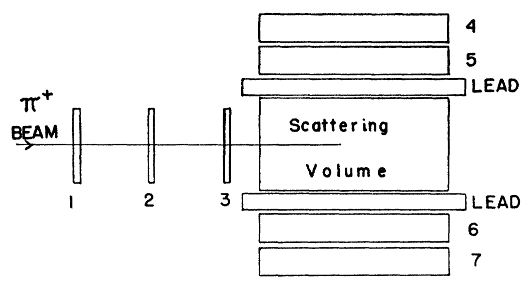

FIG. 1. Experimental arrangement.

the incident 50-Mev π^+ mesons defined as previously described.[3] After passing through the telescope, the mesons have a residual energy of 44 Mev and impinge upon targets of Be or D_2O. The Be target stops the mesons; that of D_2O slows them to 20 Mev. We look for pairs of γ-rays from π^0 decay by two scintillation counter telescopes 4, 5 and 6, 7, each with a Pb radiator of two radiation lengths thickness. The fraction of the total solid angle subtended is 0.06. We assume the scattering is isotropic.

Random counts are assessed by means of a channel which records the coincidence of a pulse from a coincidence in crystals 4, 5, 6, and 7 with a delayed meson pulse. This should indicate

TABLE I. Comparison of experimental result with that expected for one-millibarn cross sections for Be, D, and O.

Target	Number of mesons	Number of coincidences	Number of delayed coincidences	Estimated randoms	Residual effect	Expected for 1-mb cross section
Be	1.3×10^6	8	43	4.7	3.3 ± 3	3.7
D_2O	0.6×10^6	5	26	2.9	2.1 ± 3	1.5 from deuterium 0.75 from oxygen

the main contribution to random events, although it should be regarded as giving a lower limit. The resolving time in this channel is about 10 times greater than in the "instantaneous" channel.

The results are shown in Table I. They indicate that upper limits on the cross section for charge-exchange scattering may reasonably be set at 2 millibarns for Be, 3 mb for D, and 6 mb for O.

We have checked the operation of the apparatus before and after each run by counting cosmic-ray mesons in counters 4, 5, 6, and 7 in coincidence in the expected numbers. The counters are therefore sufficiently sensitive to detect minimum ionization particles. The various delays have been checked both by artificial pulses and by placing one of the crystals which normally was in the meson telescope so that cosmic-rays were counted by it in coincidence with counters 4, 5, 6, and 7.

Charge-exchange scattering has been calculated for π^++n and for π^-+p under various assumptions about meson theory.[4] We consider that at least one neutron in the Be^9 nucleus may be regarded as free because of the energy balance in the reaction $\pi^++Be^9\rightarrow B^9+\pi^0$. Evidence for this comes from the anomalously high production of π^- by γ-rays according to the reaction $\gamma+Be^9\rightarrow B^9+\pi^-$.[5] On the other hand, the Pauli exclusion principle may reduce the cross section in O^{16} appreciably because of the energy balance in the reaction $\pi^++O^{16}\rightarrow F^{16}+\pi^0$. The exclusion principle is also expected to reduce the cross section in D by a sizeable factor below the free neutron cross section.[6] Accordingly, the highest cross section would be expected in Be for π^+ mesons.

The low upper limit which we find for the charge exchange cross section in Be for 44-Mev π^+ mesons is to be compared with the total scattering cross section (direct plus charge exchange) of 13.3 mb which Chedester *et al.*[7] find for 85-Mev π^- mesons on protons. This would imply that the chief contribution to the 13.3 mb comes from direct scattering unless the charge-exchange cross section increases rapidly with energy. It is hoped to repeat our measurements with a more intense π^+ beam now in preparation.

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† Now at Stanford University, Palo Alto, California.

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Theory of Internal Conversion

H. R. COISH
Mathematical Physics Department, University of Manitoba, Winnipeg, Canada
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TRALLI and Goertzel,[1] under the above title, have recently set up for the first time the completely quantum-mechanical internal conversion problem, and have solved it in successive approximations. They verify the first-order correction to N_q, the rate of radiation of photons, which Taylor and Mott[2] obtained by semiclassical correspondence principle methods. In this communication we call attention to further corrections, of the same order in e^2, to the internal conversion coefficient N_e/N_q, which are obtained when the approximation for N_e is extended to the same relative order in e^2 as N_q.

Before the higher order expression for N_e can be written down correctly, it is necessary to modify the expressions (3q) and (3r) of TG for N_e and N_q—an evident necessity, since they do not satisfy the conservation equation,

$$N_e+N_q=1. \quad (1)$$

To remove this inconsistency we re-examine the evaluation

$$U_{0f}=U_{f0}^* \quad (2)$$

given in TG.[3]

In terms of the matrix elements (2*f*) of TG, Eq. (B3′) of TG may be written[4]

$$U_{f0}=i\pi H_{\omega k}^{(1)}H_{\omega 0}. \quad (3)$$

Direct comparison of the defining expressions for U_{f0} and U_{0f} (Appendix B, Secs. 1 and 4, of TG) shows U_{0f} to be the complex conjugate of $U_{f0}^{(-)}$, where $U_{f0}^{(-)}$ is obtained from U_{f0} by change of sign of η. This change of sign replaces the hankel function of the first kind by that of the second kind and reverses the sign of the whole expression:

$$U_{f0}^{(-)}=-i\pi H_{\omega k}^{(2)}H_{\omega 0}=U_{0f}^*. \quad (4)$$

We define

$$\gamma_2'=\pi U_{f0}U_{0f}, \quad (5)$$

which is complex. Redefining γ_2 as the real part of γ_2' validates Eqs. (3q), (3r) of TG for N_e, N_q and reinstates the conservation equation.

To extend the approximation for N_e we substitute Eqs. (3k), (3l) from TG into Eq. (3e) of TG.

In Eq. (3i) of TG this replaces H_{k0} by

$$H_{k0}+i\pi U_{f0}H_{k\omega}=H_{k0}-\pi^2H_{\omega 0}\Sigma H_{k\omega}H_{\omega k}^{(1)}, \quad (6)$$

where Σ has been inserted as a reminder of the summation over the spin states of the continuum electron. For future convenience we display the form which Eq. (6) takes when $k=\omega$:

$$H_{\omega 0}[1-\pi^2\Sigma H_{k\omega}H_{\omega k}^{(1)}]. \quad (7)$$

The correction term in Eq. (7) is the TM correction term which is referred to in TG.

In addition to the integration over γ-ray energies, Eq. (3i) of TG involves a summation over multipoles. If we make the usual assumption that in H_{k0} nuclear selection rules annul all but one of these (called the principal multipole), then this term of Eq. (6) contributes but one term to (3i) of TG.

In $H_{k\omega}$ of Eq. (6) this assumption does not hold and there will be a (small) number of terms of the multipole summation to contend with. We will use Σ_L to distinguish this summation.

The consequence of all this is that, in the solution (3i′) of TG for C_E, the expression U_{f0} is replaced by

$$i\pi H_{\omega 0}[H_{Ek}^{(1)}-\pi^2\Sigma_L\Sigma H_{Ek}H_{k\omega}H_{\omega k}^{(1)}] \quad (8)$$

with $k=\omega$.

In Eq. (8) the order of writing factors has been chosen such that the summations refer to repeated subscripts which are adjacent.

Now, to the same relative order in e^2 the probabilities of observing electrons and photons are, respectively,

$$N_e=\pi^3(\gamma_1+\gamma_2)^{-1}|H_{\omega 0}|^2\Sigma|H_{\omega k}^{(1)}-\pi^2\Sigma_L\Sigma H_{\omega k}H_{k\omega}H_{\omega k}^{(1)}|^2, \quad (9)$$

$$N_q=\pi(\gamma_1+\gamma_2)^{-1}|H_{\omega 0}|^2|1-\pi^2\Sigma H_{k\omega}H_{\omega k}^{(1)}|^2, \quad (10)$$

and finally the internal conversion coefficient is

$$\frac{N_e}{N_q}=\pi^2\Sigma\left|\frac{H_{\omega k}^{(1)}-\pi^2\Sigma_L\Sigma H_{\omega k}H_{k\omega}H_{\omega k}^{(1)}}{1-\pi^2\Sigma H_{k\omega}H_{\omega k}^{(1)}}\right|^2. \quad (11)$$