publications by Gross and Korshunow,[11] and by Vuks[12] who reach the same conclusions as the French and Indian physicists as to the nature of the low frequency lines. But polarization measurements are necessary to check these conclusions and to determine the orientations of the axes of molecular rotatory oscillation relative to the known crystallographic axes. These rotatory oscillations which appear in the spectra of the light scattered by crystals are included amongst the $3N-6$ fundamental oscillations of the crystal lattice[13] and form optical branches of the spectrum of the elastic vibrations of crystals.

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Electron-Neutrino Angular Correlation in Beta-Decay

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BLOCH and Moller have noted[1] an expected correlation between the directions of emission of electron and neutrino in beta-decay; for allowed Fermi transitions they predict a correlation function $W(\theta)\approx(1+\cos\theta)$ for the relative probability of decay with the angle θ between these two directions. Observations on the recoil nucleus[2] have tended to consistency with the above correlation function.

The present note concerns the specific correlation functions for the allowed and first forbidden transitions corresponding to the five invariant forms of beta-interaction. The results of primary interest are the following: (1) even for allowed transitions the correlation functions (in contrast to the energy spectra) are markedly different for the different possible interactions; (2) with increasing order of forbiddenness, emission of the neutrino in the same direction as the electron is increasingly emphasized.

The calculations reported assume plane-wave electrons ($Z\approx 0$, high energies) and are similar to the calculations of electron energy spectra;[3] averaging $W(\theta)$ over θ gives the spectrum correction factors of Konopinski and Uhlenbeck. The correlation functions follow:

Correlation Functions $W(\theta)$

Allowed transitions (W_0):

Scalar:	$W_{0S}=1-(p/E)\cos\theta;$
Polar vector: (Fermi)	$W_{0V}=1+(p/E)\cos\theta;$
Tensor: (Gamow-Teller)	$W_{0T}=1+\frac{1}{3}(p/E)\cos\theta;$
Axial vector:	$W_{0A}=1-\frac{1}{3}(p/E)\cos\theta;$
Pseudoscalar:	$W_{0P}=1-(p/E)\cos\theta.$

First forbidden transitions (W_1):

$$3W_{1S}=\left|\int\mathbf{r}\right|[1-(p/E)\cos\theta](p^2+q^2+2pq\cos\theta),$$

$$\begin{aligned}4W_{1V}=&\left|\int\mathbf{r}\right|[1+(p/E)\cos\theta](p^2+q^2+2pq\cos\theta)\\&+\left|\int\boldsymbol{\alpha}\right|^2(3-p\cos\theta/E)\\&+\left\{\left(\int\mathbf{r}\right)^*\cdot\left(\int\boldsymbol{\alpha}\right)-\mathrm{cc}\right\}\\&\times[q+p\cos\theta+(p/E)(p+q\cos\theta)],\end{aligned}$$

$$\begin{aligned}3W_{1T}=&\frac{1}{20}(\Sigma_{ij}|B_{ij}|^2)\left[\left(5+\frac{p}{E}\cos\theta\right)(p^2+q^2+2pq\cos\theta)\right.\\&\left.-\frac{p^2q}{E}\sin^2\theta\right]+\frac{1}{2}\left|\int\boldsymbol{\sigma}\times\mathbf{r}\right|^2\left[(1+\frac{p}{E}\cos\theta)\right.\\&\left.\times(p^2+q^2+2pq\cos\theta)+\frac{p^2q}{E}\sin^2\theta\right]\\&+\left|\int\boldsymbol{\alpha}\right|^2\left(3+\frac{p}{E}\cos\theta\right)-\left\{\left(\int\boldsymbol{\sigma}\times\mathbf{r}\right)^*\right.\\&\left.\cdot\left(\int\boldsymbol{\alpha}\right)+\mathrm{cc}\right\}\left[q+p\cos\theta+\frac{p}{E}(p+q\cos\theta)\right]\\&+\frac{1}{3}\left|\int\mathbf{r}\cdot\boldsymbol{\sigma}\right|^2\left[\left(1-\frac{p}{E}\cos\theta\right)\right.\\&\left.\times(p^2+q^2+2pq\cos\theta)-\frac{2p^2q}{E}\sin^2\theta\right],\end{aligned}$$

$$\begin{aligned}3W_{1A}=&\frac{1}{20}(\Sigma_{ij}|B_{ij}|^2)\left[\left(5-\frac{p}{E}\cos\theta\right)(p^2+q^2+2pq\cos\theta)\right.\\&\left.+\frac{p^2q}{E}\sin^2\theta\right]+\frac{1}{2}\left|\int\boldsymbol{\sigma}\times\mathbf{r}\right|^2\left[\left(1-\frac{p}{E}\cos\theta\right)\right.\\&\left.\times(p^2+q^2+2pq\cos\theta)-\frac{p^2q}{E}\sin^2\theta\right]\\&+\frac{1}{3}\left|\int\mathbf{r}\cdot\boldsymbol{\sigma}\right|^2\left[\left(1+\frac{p}{E}\cos\theta\right)(p^2+q^2+2pq\cos\theta)\right.\\&\left.+\frac{2p^2q}{E}\sin^2\theta\right]+3\left|\int\gamma_5\right|^2\left(1+\frac{p}{E}\cos\theta\right)\\&+i\left\{\left(\int\mathbf{r}\cdot\boldsymbol{\sigma}\right)^*\left(\int\gamma_5\right)-\mathrm{cc}\right\}\\&\times\left[(q+p\cos\theta)+\frac{p}{E}(p+q\cos\theta)\right],\end{aligned}$$

$$3W_{1P}=\left|\int\gamma_5\mathbf{r}\right|^2\left(1-\frac{p}{E}\cos\theta\right)(p^2+q^2+2pq\cos\theta).$$

For notation, see reference 3. Electron and neutrino momenta are p and q in units of mc; E is total electron energy in units of mc^2; $E^2=p^2+1$. The abbreviated integrals represent the nuclear matrix elements which determine selection rules and (in part) transition probabilities. Forbidden transitions may in some cases occur *via* the non-vanishing of any of several matrix elements, hence the multiplicity of terms for W_{1V}, W_{1T}, W_{1A}. In specific cases many of these terms vanish; only for $\Delta I=0$ are the complete expressions necessary.

Of the two above introductory generalizations of the results, the second is less clearcut and obvious, and hence will be elaborated. The complication of $W(\theta)$ for first forbidden transitions derives in part from the fact that these transitions may be allowed either by retardation of electron and neutrino waves across the nucleus (i.e., $(\mathbf{p}+\mathbf{q})\cdot\mathbf{r}\neq 0$) or by the presence in the interaction energy of a small term of order $v/c=$(nucleon velocity)/(velocity of light)$\ll 1$. The basis for the earlier generalization lies in the "constructive interference" effect of the retardation, represented by the introduction into $W(\theta)$ of expressions such as $(p^2+q^2+2pq\cos\theta)\equiv|\mathbf{p}+\mathbf{q}|^2$.

Thus at the midpoint of the spectrum, with $E\approx p\approx q$, the angular dependence of W_1 is most pronounced; the over-all effect of retardation, particularly if $p\gg 1$, is to produce a strong similarity between W_1 and $W_0(1+\cos\theta)$. On the other hand, the factor $|\mathbf{p}+\mathbf{q}|^2$ becomes nearly independent of θ at the upper and lower ends of the spectrum; here W_1 is therefore more isotropic than at the midpoint, and tends to be similar to W_0.

Although first forbidden transitions may occur by grace either of the retardation factor $(\mathbf{p}+\mathbf{q})\cdot\mathbf{r}$ or of the small "v/c" term, more highly forbidden transitions occur only *via* increasingly high powers of $(\mathbf{p}+\mathbf{q})\cdot\mathbf{r}$. Thus the factor $(1+\cos\theta)$ will enter the midpoint correlation function without exception and to higher powers, so that the preference for forward neutrino emission will become more and more marked; a factor $(1-\cos\theta)$, such as will occur for W_{nS} or W_{nP}, may make $W(0)=0$ but the "center of gravity" of the emission will still be in the forward direction.

Thus the predicted correlations for allowed transitions depend markedly upon choice of interaction and the correlation effect furthermore appears to possess a simple asymptotic dependence on order of forbiddenness.

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On the Magnetic Moment of the Triton*

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THE recent determination of the magnetic moment of the triton by Anderson and Novick[1] leads to the somewhat surprising result that the moment is slightly greater than the proton moment. This result is surprising because the moment in a ^2P or ^4P or ^4D state, which are the only states that can be admixed with the ^2S state of this nucleus,[2] might be expected to be smaller than the proton moment. Therefore, one might expect that any admixture of these states would lead to a smaller moment than that in the pure S state. It should be pointed out first that, although this statement is correct for the ^2P and ^4P states, in a pure ^4D state the moment need not be less than the proton moment because this state may be formed by combining a wave function which is symmetric for the interchange of $\boldsymbol{\rho}$ and $\mathbf{r}$ and an anti-symmetric function.[3] Here $\boldsymbol{\rho}$ and $\mathbf{r}$ are the distance between the neutrons and the distance from the center of gravity of the neutrons to the proton, respectively. The interference between these symmetric and anti-symmetric functions may lead to a very high moment if the wave function contains states in which the individual particles have sufficiently high orbital angular momenta. However, it seems probable that this latter requirement is not satisfied since the orbital angular momenta of the individual particles probably are small in the ground state. Under this condition the moment in the D state *is* less than that of the proton.

It is still possible to account for the moment of the triton by introducing an admixture of ^2P and ^4P states since there are terms in the expression for the magnetic moment which arise from interference between the ^2P and ^4P states, between the ^2S and ^2P states, and between the ^4P and ^4D states. The signs of these terms depend on the relative phases of the wave functions so that they may be positive. An estimate of their order of magnitude can be made if one makes assumptions consistent with keeping the orbital angular momenta of the individual particles as small as possible and at the same time assumes that the radial parts of the various wave functions are in phase throughout the nucleus. Then it is found that a 6.7 percent increase of the triton moment over the proton moment can be obtained only if the ^2P and ^4P state amplitudes are greater than the D state amplitude. The S state probability is a maximum if the D probability is taken to be zero, the ^4P probability to be 8 percent, and the ^2P probability 20 percent. This rather startling conclusion might be avoided by dropping the above assumption concerning the orbital angular momentum of the individual particles, but it appears that very high configurations indeed would be required to explain the experimental result.

If one assumes that the triton wave function contains about 20 percent ^2P state, 8 percent ^4P state and no ^4D state, then one would draw the same conclusion for He^3 and it would be anticipated that the magnitude of the moment of He^3 would be about 4.0 percent greater than the numerical value of the neutron moment.[3] A measurement of the moment of He^3 would be most valuable for obtaining further information concerning the admixture of states.

The details of these calculations, including a discussion of the other possible ways of compounding a ground state consistent with the observed magnetic moment, will soon be submitted for publication.

* This work has been carried out under the auspices of the Atomic Energy Commission. It was submitted for declassification on January 24, 1947.
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Erratum: Note on the Scattering of Radiation in an Inhomogeneous Medium

[Phys. Rev. 71, 268–269 (1947).]
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THE term $\left[\left(1+\frac{z}{r}\right)\alpha+\frac{x\beta}{r}+\frac{y\gamma}{r}\right]$ in Eqs. (6) and (7) should be changed to $\left[\left(1+\frac{z}{r}\right)\gamma+\frac{\alpha x}{r}+\frac{\beta y}{r}\right]$. In the second integral of Eq. (6) dv'' should be added.