It may be shown that the product of two quantities of anomalous parity is a normal quantity which decomposes into four quantities corresponding to the four possibilities with respect to space and time reflections. In the case of a product of a normal and an anomalous representation the corresponding quantities have anomalous parity.

Since the interaction Lagrangian must be a scalar (i.e., it must be invariant with respect to the transformations T_{01}, T_{10}, T_{11}), each term of the interaction operator must contain an even number of wave functions of particles with anomalous parity. Therefore in the case of invariance under space and time reflections the following statement must hold: if in a reaction only particles with normal parity occur then conservation of parity must hold; however, if particles with anomalous parity also take part in the reaction then conservation of normality must hold, i.e., the left and the right hand parts of the reaction equation must both contain either an even or an odd number of anomalous particles.

This argument enables us to divide particles into classes with normal and anomalous parities. If we ascribe anomalous parity to K-mesons and normal parity to π-mesons we may conclude that the Λ, Σ particles have the same normality, and so do the particles n, Ξ. For this it is sufficient for example, to consider the strong interaction reaction

$$\pi^- + p \to \Lambda^0 + \theta^0; \; K^- + p \to \Sigma^+ + \pi^-; \; \Xi^- \to K^- + \Lambda^0.$$

We have ascribed anomalous parity to the K-meson. The operator for the spatial reflection is given by the matrix T_{10} [Eq. (4)], and consequently the K-meson may exist in two states differing in their spatial parity. The masses corresponding to these two states must be the same.

From the fact that K-mesons which have anomalous parity decay into π-mesons it follows that normality is not conserved in slow reactions. Within the framework of the above explanation this is possible only in the case that the Lagrangian is not invariant under time reflections. The hypothesis proposed by Feynman with respect to the lack of invariance under spatial reflections appears to us to be improbable. On the other hand, sufficient foundations do not exist to assume that the Lagrangian is invariant under time reflections in the case of weak interactions. Such an explanation may also be related to the work of Lee and Yang[2].

We express our thanks to Ia. B. Zel'dovich and V. V. Sudakov for valuable discussions.

* The first representation contains $|k_0 + k_1|$ undotted and $|k_0 - k_1|$ dotted indices, while the second representation has these numbers reversed (in spinor notation).

** These formulas hold for integral values of k. For half-integral k in the above formulas k should be replaced by $k + ½$.

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Translated by G. M. Volkoff
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$\gamma - \gamma$ Angular Correlation in Transitions of Mesic Atoms

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(Submitted to JETP editor August 3, 1956)
J. Exptl. Theoret. Phys. (U.S.S.R.) **31**, 1090-1092 (December, 1956)

PODGORETSKII[1] has pointed out that it would be possible to determine the spin of a muon by using data on the angular correlation between gamma rays emitted in successive transitions of mesic atoms. We wish to examine this problem in the present note and also to propose a method of verifying the spins of nuclei[2] for which $I = 0$ is doubtful or has been obtained only from theoretical considerations unsupported by experiment; the formulas which are derived will be used to determine the spins of all types of mesons.

We know[3] that for light mesic atoms ($Z < 15$), the probabilities of radiation transitions are small compared with the probabilities of conversion transitions. For heavier mesic atoms with small quantum numbers (n, l), the probabilities of conversion transitions can be neglected. The following is an expression for the correlation function $W(\vartheta)$ which is suitable for not very large Z ($15 < Z < 50$)*:

$$W(\vartheta) = \sum_{k=0}^{N} A'_{2k} P_{2k}(\cos\vartheta); \quad A'_{2k} = A_{2k} b_{2k}; \tag{1}$$

$$A_{2k} = A_{2k}(L_1 L_2 j_A j_B j_C) = (-1)^{j_A - j_B}(2L_1 + 1) \tag{1a}$$
$$(2L_2 + 1)(2j_B + 1) C^{2k\,0}_{L_1 1;\, L_1 -1} C^{2k\,0}_{L_2 1;\, L_2 -1} W(j_B j_B L_1 L_1;$$
$$\times\, 2k j_A) W(j_B j_B L_2 L_2;\; 2k j_C);$$

$$b_{2k} = \sum_{F_B} (2F_B+1)^2 W^2 (j_B I\, 2kF_B;\ F_B j_B)\,/\,2I+1. \quad \text{(1b)}$$

Here L_1 and L_2 are the angular momenta of the light quanta; j_A, j_B and j_C are the total (orbital plus spin) angular momenta of the meson in the initial, intermediate and final states; and F is the sum of the mesic (j) and nuclear (I) angular momenta. In (1b), it was considered that for these mesic atoms the ratio of the hyperfine structure to the level width of the intermediate state is $\gamma_{FF'}/2\gamma_B \gg 1$. (For example, for Al, $\gamma_{FF'}/2\gamma_B \sim 10$ ev/10^{-5} ev $= 10^6$.)

Formula (1), which was derived on the assumption that the nuclear spin does not change in mesic-atom transitions, agrees in form with the function obtained by Alder[5] for the angular correlation of gamma rays emitted by a nucleus. This expression can be used to verify the spins of nuclei (such as $_{16}S^{34}$, $_{20}Ca^{40}$ and $_{34}S^{74}$) for which $I = 0$ has not been confirmed experimentally.

As an example, we note that the anisotropy is $A = 0.43$ and 0.25 for the transitions 1/2(D)3/2(D)1/2 with $I = 0$ and 1/2, respectively.

For heavy mesic atoms, finiteness of the nucleus requires the calculation of the correlation function in transitions of the type $l_A(L_1)l_B(L_2)l_C$ where l_A, l_B and l_C are the orbital angular momenta of the meson in the initial intermediate and final states, respectively. In this case the fine structure must be taken into account, as well as the hyperfine structure. Their contribution results from the fact that, because of the spin-orbit interaction, after emission of the first quantum, the direction of the orbital angular momentum is changed in the intermediate state, while interaction with the nucleus results in a change of direction of the total angular momentum j. These effects are important because the lifetime of the intermediate state exceeds the precessional periods of the angular momenta. (For example, for lead $\nu_{jj'} \sim 200$ kev, $\nu_{FF'} \sim 3$ kev, $2\gamma \sim 1$ kev.)

Thus for heavy mesic atoms, confining ourselves to electric transitions (which are the most important) we obtain

$$W(\vartheta) = \sum_{k=0}^{N} A'_{2k} P_{2k}(\cos\vartheta), \quad (2)$$

$$A'_{2k} = A_{2k}(L_1 L_2 l_A l_B l_C)\, b_{2k}; \quad \text{(2a)**}$$

$$b_{2k} = \sum_{F_B F'_B j_\beta j'_\beta} \frac{(2F_B+1)(2F'_B+1) W^2 (j_\beta I 2kF'_B;\ F_B j'_\beta)}{(2I+1)(2s+1)[1+(\nu_{FF'}/2\gamma_B)^2]} \times (2j_\beta+1)(2j'_\beta+1) W^2 (l_B s\, 2kj'_\beta;\ j_\beta l_B), \quad \text{(2b)}$$

with both the fine structure and the hyperfine structure entering into $\nu_{FF'}$.

For a hyperfine structure which is small compared with $2\gamma_B$, Eq. (2) will reduce to Alder's function (as occurs for $I = 0$).

Any additional interaction can be taken into account by an analogous change in b_{2k}. In particular, for the mesic atoms under consideration, there arises the question of taking into account the interaction with the electron shells. However, because of the small splitting with $2\gamma_B$ the resulting b_{2k} reduces to (2b).

Since for the mesic atoms under consideration $\nu_{jj'}/2\gamma_B \gg 1$.

$$b_{2k} = \sum_{F_B F'_B j_\beta} \frac{(2F_B+1)(2F'_B+1) W^2(j_B I 2kF'_B;\ F_B j_\beta)(2j_\beta+1)^2 W^2(l_B s\, 2kj_\beta;\ j_\beta l_B)}{(2I+1)(2s+1)[1+(\nu_{FF'}/2\gamma_B)^2]}, \quad (3)$$

where $\nu_{FF'}$ is the sum of the splittings induced by the interactions of the nuclear magnetic dipole and electric quadrupole moments with the meson.

Denoting b_{2k} by means of $b^{sl}_{2k}(l_B)$, we have;

$$b^{sl}_0(l_B) = 1, \quad \text{(3a)}$$

$$b^{00}_{2k}(l_B) = 1, \quad \text{(3b)}$$

$$b^{s0}_{2k}(l_B) = \sum_{j_\beta} \frac{(2j_\beta+1)^2 W^2(l_B s\, 2kj_\beta;\ j_\beta l_B)}{2s+1}; \quad \text{(3c)}$$

$$b^{s\,1/2}_{2k}(l_B) = \frac{1}{1+(\nu/2\gamma_B)^2} \sum_{F_B j_\beta} \left[1+\frac{1}{2}\left(\frac{\nu}{2\gamma_B}\right)^2 \times (2F_B+1)^2 W^2\left(j_\beta \tfrac{1}{2}\ 2kF_B;\ F_B j_\beta\right)\right] \times \frac{(2j_\beta+1)^2 W^2(l_B s\, 2kj_\beta;\ j_\beta l_B)}{2s+1}; \quad \text{(3d)}$$

$$b_{2k}^{s>1/2\, I>1/2}(l_B)=\sum_{F_B j_\beta}\frac{(2F_B+1)^2 W^2(j_\beta I 2k F_B;\ F_B j_\beta)(2j_\beta+1)^2 W^2(l_B s 2k j_\beta;\ j_\beta l_B)}{(2I+1)(2s+1)}. \qquad (3e)$$

We see from (3a) that the renormalization $\int W(\vartheta)\, do/4\pi = 1$ is insured. In the absence of interactions, the "reduction factor" b_{2k} has its maximum value (= 1) (3*b*). The special case $I = 0$ (3c) was examined by Podgoretskii[1], who did not, however, take the fine structure into account. His criterion for deciding whether the spin of a μ meson is 1/2 or 3/2 in the transition $3p \to 2s \to 2p$ is incorrect, since it follows from (2) that in both instances the distribution is isotropic.

In (3d), ν is the hyperfine structure of a mesic atom which results from the interaction of the nuclear and mesic magnetic moments. In (3e), it is considered that the splitting which results from the electric quadrupole interaction is of the order of magnitude of the spin-orbit coupling[6], i.e., $\nu_{FF'}/2\gamma_B \gg 1$.

Following are the values of the anisotropy A for the radiative transition $2s \to 2p \to 1s$ for different μ-meson spins (with $I = 0$):

$s=0$	$1/2$	1	$3/2$
$A=1$	0.273	0.225	0.197

Substituting for lead $(\nu/2\gamma)^2 \doteq 9$, we get

$$I = 1/2 \qquad s = 1/2 \qquad A = 0.175$$
$$s = 3/2 \qquad A = 0.150.$$

Thus, measurement of the anisotropy A with an accuracy which makes it possible to distinguish a difference of 0.08 is sufficient to determine the spin of the μ meson when the nuclear spin is zero with mesic spin 1/2; then it is also sufficient to determine whether the nucleus has zero spin (for example, $_{74}W^{182}$, $_{78}Pt^{194}$ and $_{82}Pb^{204}$).

I am deeply grateful to Professor I. Ia. Pomeranchuk for suggesting the problem and to K. A. Ter-Martirosian and L. M. Afrikian for their interest.

* In deriving this as well as the following expression we used the well-known contraction relation of Clebsch-Gordon coefficients and also the contraction relation of Racah coefficients[4]:

$$\sum_\lambda (2\lambda+1)\, W(a'\lambda\alpha c;\ ac')\, W(b\lambda\beta c';\ b'c)\, W(a'\lambda\gamma b;\ ab') = W(a\alpha b\beta;\ c\gamma)\, W(a'\alpha b'\beta;\ c'\gamma).$$

** See (1a).

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Translated by I. Emin
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Dielectric Properties of Alkali-Halide Single Crystals

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(Submitted to JETP editor September 24, 1956)
J. Exptl. Theoret. Phys. (U.S.S.R.) 31, 1110-1111 (December, 1956)

SOME time ago, it was established[1] that the dielectric losses (tan δ) of alkali-halide crystals are determined by conductivity losses. Breckenridge[2], studying the properties of certain alkali-halide crystals and the silver halides, was the first to find that after preliminary heat treatment of these crystals, small maxima of relaxation losses of the Debye type were observed in the value of tan δ. Many authors have attempted to reproduce these results. Some of them[3-6] succeeded in observing relaxation losses in these crystals; however, the results of the observations of different authors were contradictory. We have undertaken a careful study of the dielectric properties of alkali-halide crystals, especially the nature of losses in them.

In contrast to the investigations of previous authors, we have carried out a study of both temperature and frequency dependencies of the dielectric constant and tan δ, not only under atmospheric conditions, but also in a vacuum, over a wide range of temperatures and frequencies (from $-170°$ to $330°$ and from 10^2 to 10^7 cps under atmospheric conditions, and from $-140°$ to $550°$ and from 10^2 to 10^6 cps in a vacuum). We studied single crystals of LiF, NaCl, KCl, KBr, CsBr, KJ, KPC-5 and KCl-KBr, both pure and with impurities of Ag, Cu, Tl, Cd, Pb, In, introduced in