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

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.

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* 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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Dielectric Properties of Alkali-Halide Single Crystals

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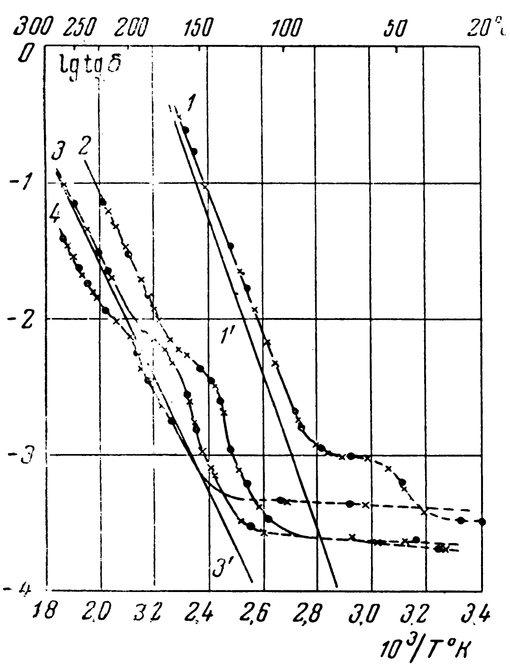
SOME time ago, it was established[1] that the dielectric losses (tan δ) of alkali-halide crystals are determined by conductivity losses. Breckenridge[2], studying the properties of certain alkali-halide crystals and the silver halides, was the first to find that after preliminary heat treatment of these 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



Frequency: *1* = 1 kc, *2* = 300 kc, *3* = 1 mc, *4* = 4.75 mc; *points* – direct process, *circles* – reverse process *Upper scale* – °C.

various concentrations. Growth of crystals was carried out in various crucibles; porcelain, enamel, corundum, fire clay, quartz. The crystals of LiF and KPC-5 were not grown by us). Prepared plane-parallel specimens (ground or polished to within 1-2μ) had areas of 15-20 cm^2 and thickness 0.26-1 mm, the capacity of the specimens amounting to 70-200 mmfd.

Various methods of coating the electrodes were used: silver and platinum platings compressed into pastes, glued foils, aquadag coating, vacuum evaporation of Al, Ag, Au. However, it appeared that the method of "optical trimming" appeared to be most suitable (in this method, the specimen was not subjected to thermal treatment and was not contaminated, while hygroscopic specimens could always be measured also). The specimens were tightly compressed onto flat (machined with an accuracy to within 2μ) electrodes of chemically pure iron which does not react with the alkali-halides at elevated temperatures.

In the temperature and frequency curves of tan δ, there were discovered relaxation maxima in all specimens, which were not subjected to additional thermal treatment. In "pure" monocrystals, as a rule, there was a single maximum; in crystals with impurities, up to four maxima. (By way of illustration, curves are given in the Figure for LiF at atmospheric pressure). After heat working at high temperatures, these maxima were leveled down. The majority of the relaxation maxima at high frequencies were observed in a temperature region where the absolute value of tan δ was of the order of 10^{-3}-10^{-1}. (In this region, the loss measurements on a Q-meter were reliable.)

We also investigated the electric conductivity of crystals γ in a vacuum at constant pressure. For some crystals with impurities, an additional "break" in ln γ was established near 200°, with a temperature dependence. In the case of thermal working of the crystals near the melting point, the values of tan δ and γ declined somewhat.

From a comparison of tan δ, computed from γ (the straight lines 1′ and 3′ in the Figure), with the experimental values of tan δ, it follows that the losses of conductivity are fundamental down to 40-50° at low frequencies, but only to 150-200° at higher frequencies; at the lowest temperatures, significant departures from this rule were noted.

The low temperature "tails" (dashed lines in the Figure) of the curves for tan δ are located in a region of very small losses, and the sensitivity of the Q-meter is insufficient for the investigation of these losses. With the aid of sensitive apparatus (at $f \sim 10^7$ cps) we measured tan δ for 20° for CsBr, LiF and NaCl. The losses were of the order of (3-5) × 10^{-5}.

The magnitudes of the activation energy U were calculated by the usual method from various pairs of temperature and frequency curves of tan δ. It turns out that the values of U coincide with accuracy to within ± 0.1 ev. The values of U for different crystals are equal to 0.7-1 ev.

As optical and polarographic investigations have shown, the amount of impurities in the crystal resulting from the fusion amount to 6-10%. Here it is characteristic that there are impurities entering into the crystal which are not specially introduced in the fusion. In view of the significant effect on its properties of the previous history of the specimen the whole cycle of measurement of γ, ϵ and tan δ was carried out on the same specimen as a rule.

The relaxation losses that we have observed in the crystals studied can be explained by the reorientation of complex pairs: bivalent impurity ion + cation vacancy[2], cation vacancy + anion vacancy[2,7], and also by the interaction of the vacancy with a dislocation (in particular, with point dislocations). The theoretically computed values of U of the "complexes", as is well known, are of the order of 0.4-0.6 ev, which is somewhat lower than our experimental values.

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