TABLE I. Summary of results.

Lead in cm	Date	Total time in hours	Total number of counts	Mean temperature	Correl. coefficient	Temperature effect
0	1941 VI	662.7	165	20.7°	−0.702	−0.243 ± 0.084
	1942 XII	477.1	125	0.1		
	1943 III	192.9	46	10.3		
10	1941 VII	466.5	94	20.2	+0.914	+1.015 ± 0.077
	1941 IX	520.5	106	15.4		
	1943 II	343.8	59	4.6		
15	1941 IX	321.2	75	13.4	+0.939	+1.152 ± 0.070
	1941 XII	383.4	74	−2.1		
	1943 II	356.4	78	2.9		
20	1941 X	230.0	55	5.6	+0.279	+0.861 ± 1.35
	1941 XI	249.8	45	1.1		
	1943 I	478.0	106	−2.2		
25	1941 III	284.0	52	0.7	+0.950	+0.793 ± 0.039
	1941 X	305.2	57	7.0		
	1943 I	359.2	61	−5.0		
35	1941 I	416.5	76	−2.7	+0.530	+0.400 ± 0.26
	1941 V	366.4	68	18.3		
	1943 VI	398.0	85	16.5		
40	1940 XII	312.7	57	−8.0	+0.107	+0.082 ± 0.36
	1941 X	344.7	57	12.0		
		327.0	65	15.2		
45	1941 II	333.9	60	2.0	+0.780	+1.06 ± 0.25
	1941 IV	429.8	77	10.0		
	1943 V	439.5	91	14.8		
50	1941 III	406.5	59	4.4	+0.946	+1.562 ± 0.082
	1941 IV	408.8	80	10.0		
	1943 IV	411.8	83	15.2		

sea level:

$$\frac{1}{L}\frac{dL}{dt}=0.16\pm0.03 \text{ percent per °C}.$$

The temperature effect of the meson intensity at sea level,

$$\frac{1}{I_\mu}\frac{dI_\mu}{dt}=\frac{L}{l}\times 0.16 \text{ percent per °C},$$

can theoretically be as well greater or smaller than 0.16 percent in conformance to the mean free path of the mesons before decay, l being smaller or greater than L. For the temperature effect of the neutrini, created at the decay of the mesons, we obtain:

$$\frac{1}{I_\nu}\frac{dI_\nu}{dt}=\frac{L}{l}\,\frac{\exp[-L/l]}{1-\exp[-L/l]}\cdot 0.16 \leqq 0.16 \text{ percent per °C};$$

hence, theoretically, it can only have values smaller or equal to 0.16 percent per °C, whereas the experimental value is about five times greater.

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[1] L. Jánossy and G. D. Rochester, Proc. Roy. Soc. London **A183**, 186 (1944).

[2] J. Barnóthy and M. Forró, Zeits. f. Physik **104**, 744 (1937); Phys. Rev. **53**, 848 (1938); Phys. Rev. **55**, 868 (1939); Phys. Rev. **58**, 844 (1940).

[3] J. Barnóthy, Zeits. f. Physik **115**, 140 (1940).

Atomic Absorption Coefficient for X-Rays

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In a previous paper[1] it was shown that the mass absorption coefficient for any given element could be calculated from the empirically derived expression:

$$\frac{\mu}{\rho}=(C\lambda^3-D\lambda^4)+\sigma_e Z\frac{N_0}{A}.$$

Further work has led to an expression which may be of theoretical significance.

It has been found that the atomic absorption coefficient τ_a, for any element and between any two critical absorption wave-lengths, may be represented within the accuracy of observational error by the expression:

$$\tau_a=\left\{\frac{\nu_1\nu_2}{\nu^3}-\frac{\nu_1\nu_2\nu_3}{\nu^4}\right\}K,$$

where ν is the frequency of the incident radiation, and ν_1, ν_2, and ν_3 are apparently critical frequencies resulting from rational quantized transitions within an atom of atomic number Z. K is an invariable constant. A manuscript on the subject is now in preparation and will be published shortly.

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[1] J. A. Victoreen, J. App. Phys. **14**, 95 (1943).

Electrostrictive Effect in Barium Titanate

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In a recent paper[1] and in his thesis Shepard Roberts has demonstrated a new type of electrostrictive effect in a ceramic piece made up of polycrystalline barium titanate. In this effect mechanical resonances can be excited by a small applied alternating voltage when either a high direct-current field, or a remanence polarization induced by a high direct-current field, are present. Roberts identified the lowest frequency modes as radial vibrations of the disk, but, although his data show it, he failed to identify the thickness mode with a very high electromechanical coupling. Further measurements have been made by the writer of the radial and thickness modes of barium titanate disks as a function of the applied field. Considering the device as an electromechanical vibrator,[2] the data on the resonance frequency, the separation of resonance and antiresonance frequencies, and the capacity of the crystal give enough data to determine the electromechanical coupling factor k, the elastic constant for radial vibrations (Young's modulus), the elastic constant for the longitudinal thickness mode ($c_{11}=\lambda+2\mu$), and the electrostrictive constants. The elastic constants are

$$Y_0=\frac{\mu(3\lambda+3\mu)}{\lambda+\mu}=9.1\times10^{11}\text{ dyne/cm}^2; \quad (1)$$
$$\lambda+2\mu=1.16\times10^{12}\text{ dyne/cm}^2.$$

From these we can determine

$$\lambda=4.4\times10^{11};\quad \mu=3.8\times10^{11};\quad \sigma=\text{Poisson's ratio}=0.27. \quad (2)$$

The electrostriction constants for the two modes are shown plotted in Fig. 1 for ascending and descending

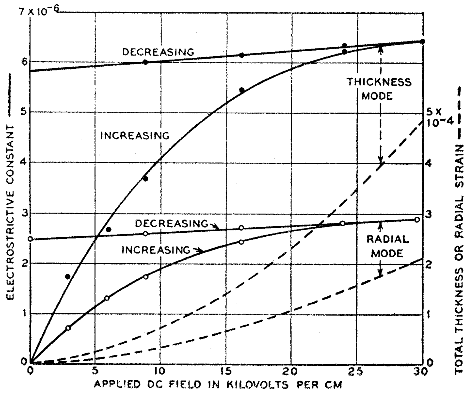

FIG. 1.

voltage gradients. The thickness constant is about twice that for the radial motion. After removing the polarization voltages of 30,000 volts per centimeters, the remanence polarization is enough to give a high coupling. Since the electrostriction constant is the slope of the electrostriction expansion-voltage curve, the total thickness and radial expansions can be obtained by integrating these curves, and the results are shown by the dotted lines of Fig. 1. The total increase in thickness is 5 parts in 10,000 up to a voltage gradient of 30,000 volts per centimeter.

The discovery of the thickness effect, and the ratio of its electrostrictive constant of about 2 to 1 to that for the radial mode, allows one to obtain a mechanism for this effect. Barium titanate above 120°C has a cubic structure, but at room temperature it becomes ferro-electric and has expanded by two-thirds of one percent[3] along the direction of the ferro-electric axis, and contracted one-third of one percent along the other two axes. In a polycrystalline body, the domains are distributed in all directions. The application of a high direct-current field lines up a certain percentage of the domains along the direction of the field. Since if all the domains were lined up the thickness would increase by two-thirds percent or 6.6×10^{-3}, the data of Fig. 1 indicate that

$$\frac{5\times 10^{-4}}{6.6\times 10^{-3}}=.075, \tag{3}$$

or 7.5 percent of the domains are lined up by a field of 30,000 volts per centimeter. Since the small alternating voltage superimposed on the direct-current field is too small to cause domains as a whole to change orientation, its principal effect is probably the transferring of molecules from domains not lined up with the field to domains lined up with the field, across their common boundary, when the alternating current field adds to the direct-current field and the reverse process when the two are opposing. When more molecules are in the domains lined up with the field, the crystal increases in thickness by a certain percentage and decreases in a radial direction by about half as much. When fewer molecules are in the lined-up domains, the reverse process occurs. Since the transfer of molecules from one domain to another lags behind the applied field, this is the cause of the dielectric hysteresis that lowers the Q of the vibrations to about 15. The transfer of molecules between adjacent domains can go on for an alternating field without a biasing polarization, but it cannot change the thickness unless a polarization bias exists.

[1] Shepard Roberts, "*Dielectric and piezoelectric properties of barium titanate*," Phys. Rev. **71**, 890 (1947).
[2] See, for example, W. P. Mason, "*Properties of monoclinic crystals*," Phys. Rev. **70**, 705 (1946).
[3] H. D. Megaw, Proc. Roy. Soc. **189**, 261 (1947).

Angular Correlation of Successive Gamma-Ray Quanta

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THEORETICAL considerations[1,2] predict a directional correlation of successive quanta of the form

$$W(\theta)=1+\sum_{i=1}^{l} A_i \cos^{2i}\theta$$

if $2l$ is the highest multipole order occurring. Attempts to demonstrate this effect experimentally have heretofore been inconclusive.[3] We have studied coincidences between successive gamma-rays of Co^{60}, Sc^{46}, Y^{86} (106 day), and Cs^{134} at angles 180° and 90° between the counters, and found a pronounced anisotropy in the first two named and no correlation within the experimental error in the last two. Our results, together with the gamma-ray energies concerned, are shown in Table I. The quantity $(W(\pi)-W(\pi/2))/W(\pi/2)$ should be equal to ΣA_i. Our results for this quantity, denoted by ϵ in Table I, should be increased by about six percent, because of finite angular resolution, and by an unknown, but probably small, correction arising from scattering in the source. The angular resolution of about ±15° was determined experimentally by measurements on annihilation radiation. Possible important effects attributable to interatomic fields[1] were shown to be absent in the case of Co^{60}, which was studied in the form of solid chloride, in aqueous solution, and as gaseous cobalt-nitrosyl-carbonyl. The respective values of ϵ were 0.19±0.04, 0.20±0.04, and 0.22±0.04.

TABLE I. Anisotropy of gamma-ray coincidences.

Source	Co^{60}	Sc^{46}	Y^{86}	Cs^{134}
ϵ	0.21±0.025	0.20±0.035	−0.05±0.03	0.01±0.04
Gamma-rays Mev	1.1, 1.3	0.89, 1.12	0.91, 1.89	0.58, 0.78
Reference	4	5	6	7

Spurious angular correlations can be caused by small contaminations by positron-emitting substances. This was ruled out in the case of our samples of cobalt and scandium by observing, with greatly improved angular resolution, coincidences from stronger samples of the same preparations. In this arrangement the effect of annihilation radiation would be greatly emphasized. It was found that no