found two bands, one at 5250A and the other at 3700A. The additive color centers can be produced at high temperatures only. The absorption bands were obtained only if the crystals are cooled down to room temperature very rapidly. When they were cooled slowly no absorption bands were found. By proper cooling the shape and position of the band in the visible could be changed (probably resulted in the formation of colloids).

As compared with alkali halides, the absorption spectra of colored calcium and barium fluorides show some similar and some different properties. These similar properties can be noted: saturation of coloration with exposure time; half-widths of absorption bands; and bleaching by heat or light.

The differences are as follows: Only two bands appear in alkali halides after a small exposure to x-rays, as was the case here; one is the strong band, called the *F*-band after Pohl;[1] and the other a weak band, called the *M*-band after Seitz[4] (the *M*-bands were discovered by Ottmer[5] and later investigated by Molnar[6]). In calcium fluoride and in barium fluoride, at least four bands can be seen. In alkali halides the *F*-band can be transformed into the *M*-band by exposure to the light absorbed by the former. In calcium fluoride and barium fluoride, the transformation of one band to another one seems to be impossible, at least at room temperature. The relationship, vd^2 = constant (v = frequency of the *F*-band, d = lattice constant) which has been found by Mollwo[7] for *F*-bands of alkali halides is not valid for any of the bands of calcium fluoride and barium fluoride.

From preliminary experiments on bleaching by heat and light one can assume that the absorption bands of the color centers in calcium fluoride and barium fluoride are independent. Although the nature of color centers may be generally the same as in alkali halides, electrons trapped in lattice defects, further investigations are necessary for their quantitative explanation.

Grateful acknowledgment is given Mrs. R. K. Wilkinson for transmission measurements.

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Gamma-Rays of K^{40}

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The gamma-ray emitted by K^{40} has been reported as 1.55 Mev by absorption in lead, and no evidence for softer gamma-rays was found.[1,2]. The scintillation spectrometer has been used to investigate the K^{40} gamma-radiation and to search for annihilation radiation associated with possible positron emission.

The gamma-rays produce Compton electrons in an anthracene crystal and the spectrum of these Compton electrons is measured by determining the pulse distribution from an RCA C-7132 photomultiplier to which the anthracene crystal is cemented.

Figure 1 shows the arrangement of the sample (which was 1300 g of normal KCl) and the anthracene crystal and photo-multiplier. The beta-rays were absorbed by the $\frac{1}{8}$-inch aluminum wall surrounding the crystal. The entire assembly was shielded by 2 inches of lead.

The gamma-ray was compared with the low energy gamma-ray from Na^{24}(1.38 Mev),[3] the gamma-ray of Zn^{65}(1.12 Mev)[4] and the conversion line of Cs^{137}(0.632 Mev).[5] The Na^{24} sample was placed on top of the KCl container leaving the KCl in place. The distribution of pulses from the K^{40} and part of the distribution

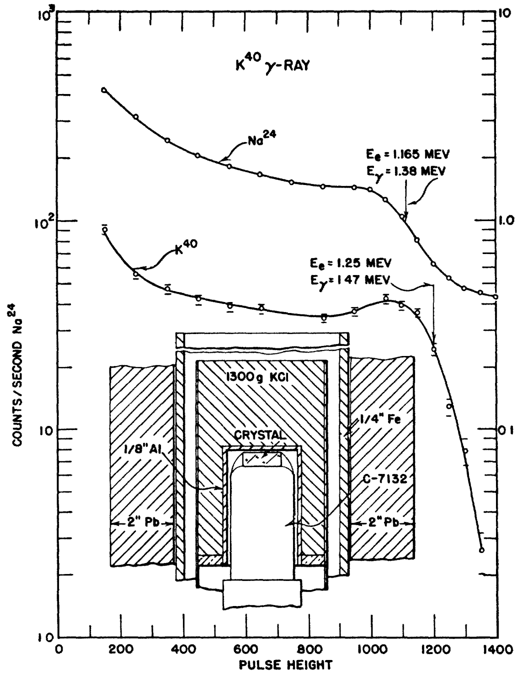

FIG. 1. Arrangement of apparatus and distribution of pulses.

produced by Na^{24} are also shown in Fig. 1. The background counting rate was quite negligible.

The maximum energy of the Compton electrons was determined in two ways: (1) the maximum slope of the break and (2) the half-counting rate point (in the case of Na^{24} the counts due to the upper gamma-ray were subtracted).

The results of several determinations are given in Table I. A search was then made for annihilation radiation. Figure 2 shows

TABLE I. Energy of Compton electrons.

Comparison radiation	Energy from Maximum slope	Energy from Half-counting rate
Na^{24}	1.47 Mev	1.49 Mev
Na^{24}	1.39 Mev	1.42 Mev
Cs^{137}	1.47 Mev	1.48 Mev
Zn^{65}	1.47 Mev	1.46 Mev
average	1.45±0.04 Mev	1.46±0.04 Mev

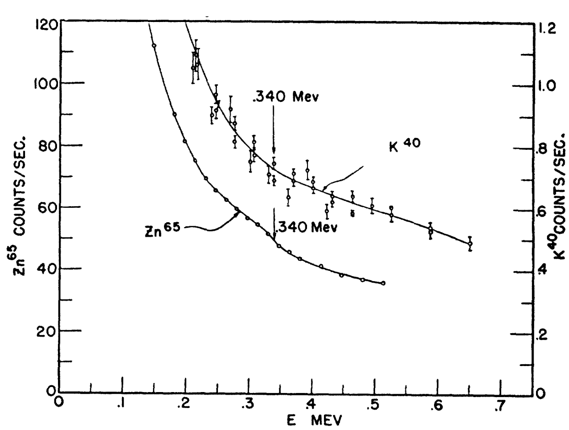

FIG. 2. Gamma-ray spectra.

the part of the gamma-ray spectrum in which a step should be found if annihilation radiation were present. Also shown is the curve obtained for the Zn^{65} spectrum in this region. Zn^{65} has about 5 annihilation quanta per 100 gamma-rays.[6] The number of annihilation quanta per gamma-ray in K^{40} must be less than half the number from Zn^{65}. Therefore the number of positrons emitted must be less than 1 percent of the K capture transitions to the excited state of A^{40}. This lack of positron emission makes it improbable that there is any large number of K captures to the ground state of A^{40}.

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Zenith Angle Dependence of Extensive Air Showers

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FROM the altitude dependence of extensive air showers one can calculate the zenith angle dependence of the showers at a given depth, under the following assumptions: (1) The shower primaries are isotropic at the top of the atmosphere, (2) the multiplication and disappearance of the shower particles in the atmosphere is a function solely of the mass of matter traversed and not of the path length or density, (3) the lateral spread of shower particles at a given depth is inversely proportional to air density in accordance with cascade theory, (4) the particles in the showers have the same direction as the primary particle which produced the shower, and (5) the value of γ, defined as $d \log C/d \log A$, where C is the counting rate and A is the counter area, is known for showers incident from the vertical.

By use of an altitude curve[1] obtained by the author, the zenith angle dependence was calculated for an atmospheric pressure of 50 cm of Hg. The shower detector consisted of three Geiger counters uniformly spaced in a straight line. Spacing between adjacent counters was 1.4 meters. The effect of counter geometry was taken into account, although the calculated zenith angle dependence is only weakly sensitive to the counter geometry. The value of γ was assumed to be constant and equal to 1.5 between sea level and 50 cm of mercury.[2] By the use of a generalized Gross transformation[3] the zenith angle distribution was then obtained as:

$$M(t,\theta)=\frac{2.2C(t/\cos\theta)-(t/\cos\theta)C'(t/\cos\theta)}{2\pi}\cos^{0.7}\theta.$$

$C(t)$ is the observed counting rate as a function of altitude. $M(t,\theta)$ is the rate of showers per steradian which would be counted at thickness t and zenith angle θ, by an isotropic detector having the same vertical sensitivity as the counter arrangement.

Numerical application of this formula to the altitude curve gives a zenith angle dependence for the axes of the air showers which can be approximately represented by $\cos^5\theta$ between 0° and 40°, but which decreases somewhat more rapidly than $\cos^5\theta$ at larger zenith angles.

An experimental test of the above zenith angle distribution was attempted at Climax, Colorado, at a pressure of 49.5 cm of mercury, by using the directional sensitivity of long cylindrical counters. When the axes of such counters are vertical, their counting rate is strongly sensitive to the breadth of the zenith angle distribution of the showers. The counting rate of these counters with their axes horizontal is less sensitive to the zenith angle distribution. Table I lists the horizontal-to-vertical counting

TABLE I. Values of the horizontal/vertical counting ratio (R), calculated for various assumed zenith angle distributions. The values were computed for cylindrical counters with a sensitive area of 2.44 cm × 33 cm.

Assumed angular distribution	Calculated value of R
$\cos^3\theta$	1.86
$\cos^5\theta$	2.33
$\cos^9\theta$	3.16
$\cos^{15}\theta$	4.21
angular distribution at 50 cm of Hg, calculated from altitude curve of reference 1	2.56

ratio for counters of lateral cross section 2.44 cm by 33 cm, having the same disposition in a horizontal plane, calculated for various assumed zenith angle distributions of the showers.

The counting rates of the counters shown in Fig. 1 were determined at Climax. The horizontal-to-vertical ratios (R) are shown in Table II. These ratios are not sensitive to the counter arrange-

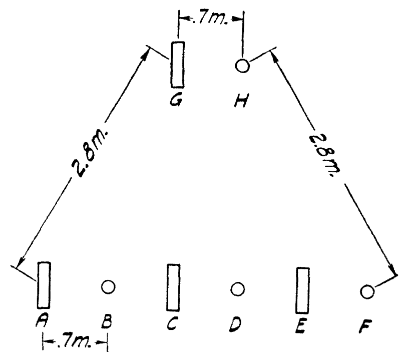

FIG. 1. Vertical view of arrangement of horizontal and vertical counters, used to test zenith angle distribution of extensive air showers at Climax, Colorado. The coincidences ACE, AEG, $ACEG$, BDF, BFH, $BDFH$, were recorded. Sensitive area of each counter is 2.44 cm by 33 cm.

TABLE II. Counting rates of the counter arrangement shown in Fig. 1.

Time	Coincidence type	Counts	Rate
220	ACE	1621	7.37 ± 0.18*
220	AEG	1563	7.11 ± 0.18
220	BDF	765	3.47 ± 0.12
220	BFH	738	3.35 ± 0.12
220	$ACEG$	1018	4.63 ± 0.15
220	BDFH	474	2.15 ± 0.10
	Coincidence ratios		R
	ACE/BDF		2.12 ± 0.08*
	AEG/BFH		2.12 ± 0.09
	$ACEG/BDFH$		2.15 ± 0.12

* This is the standard deviation due to statistical fluctuations.

ment. The best experimental value of R is 2.12±0.07. This is the value of R to be expected for a zenith angle distribution of about $\cos^4\theta$. This value is lower than the value of 2.56 which was calculated from the altitude dependence.

The cause of the above difference is not clear. Some of it is due to scattering of the shower particles in the air and to multiplication in material surrounding the counters. The counters were enclosed in boxes of 0.8-mm sheet iron, under a canvas tent in the open air. The tent was 10 feet from a metal shack about 15 feet square by 10 feet high. However, the fact that R did not vary with the counter geometry indicates that the shack did not appreciably affect its value.

Narrow showers[4] incident at large zenith angles would tend to