and negative ion vacancies, and the energy of formation of the various aggregates.

On the basis of these considerations, it seems probable that the room temperature V-bands reported by Alexander and Schneider[2] for KCl and KBr are due to halogen molecule centers and other aggregates of holes and vacancies rather than to single holes trapped at a single positive ion vacancy. In particular the 2200A band in KCl and the 2300A band in KBr which do not bleach when the F-center is irradiated are probably due to halogen molecule centers with two positive vacancies. Bleaching these centers by irradiation in the band probably involves either the thermal decomposition of the excited center into two G-centers or the splitting away of the positive ion vacancies from the halogen molecule. The slow restoration of the center is then due either to the slow migration of G-centers, or of positive ion vacancies and halogen molecules, and recombination.

* Published with the permission of the U. S. Navy Department without endorsements of statements or opinions of the writers. The authors are on the staff of the Crystal Branch, Metallurgy Division, Naval Research Laboratory, ONR, Washington, D. C. Presented at the Washington Meeting of the American Physical Society, 1950.

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Multiple Scattering of the Particles Producing the "Positive Tracks" Appearing near Beta-Ray Emitters*

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A SERIES of investigators[1-5] have observed cloud-chamber tracks in the neighborhood of beta-ray emitters of curvatures corresponding to positively charged light particles moving away from the source. From energy considerations the particles producing these tracks cannot be positrons resulting from the decay of the beta-ray emitters. While most of the investigators are of the opinion that the cloud-chamber evidence favors the existence of these positive particles (they could not be observed in beta-ray spectrographs), in some recent investigations[6-8] the "positive" tracks have been attributed (1) to electrons emerging from the source, multiply scattered in such a way that their tracks have curvatures opposite to that which would be produced by the magnetic field alone, and (2) to electrons re-entering the source after being either reflected from the walls of the chamber or traversing an (unobserved) full circle.

We have compared the multiple scattering of 20 of these positive tracks emerging from various P^{32} source[9] arrangements with that of about 100 electrons in a mixture of 2 parts argon and 3 parts helium at one atmosphere total pressure in a magnetic field of approximately 340 gauss. The minimum track length was 7 cm and the average in both groups approximately 10 cm. Use was made of a method recently described[10] in which from deflections ω_i between subsequent chords of equal length connecting a series of points of a track an estimate for the momentum and a root-mean-square angle of scattering $[(\omega^2)_{Av}]^{\frac{1}{2}}$ (see Eq. (23) of reference 10) is derived. Due to the shorter minimum length of the tracks which had to be chosen in this investigation in order to include a larger number of positive tracks, a chord length of one centimeter only had to be used for the sake of improved statistics. In a section of such a short length the condition for multiple scattering is not fulfilled in our mixture of helium and argon for the higher momenta considered by us. For the sake of better statistics tracks in the momentum range between 1500 and 2000 gauss-cm were also included, although for such low momenta the method is not suitable for the determination of an absolute (experimental) scattering law. Both facts are however of minor importance for a comparison of the scattering of two groups of particles. Figure 1 shows the individual root-mean-square angles of scattering for the 20 positive tracks and a curve ψ_1 obtained by a least-squares fit of the data obtained for 104 electrons. In all individual cases corrections were made for errors in the optics, photography, and the measurements of the deflections, as previously described.[10] The difference between the scattering of the particles responsible for the positive tracks and the electrons, which follows from an inspection of Fig. 1, seems to be significant in view of the fact that all the tracks were obtained under the same conditions and treated in the same manner, and that furthermore it was ascertained in two different ways that the difference in the spectral distributions of the particles producing the "positive tracks" and the electrons from which the 104 cases were selected cannot be responsible for the higher scattering of the positives.

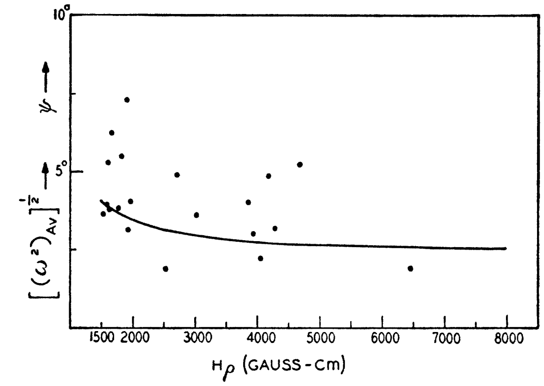

Fig. 1. Dots: root-mean-square scattering angles derived from 20 "positive tracks" as a function of $H\rho$. Curve: least-squares curve derived from the root-mean-square scattering angles of 104 electrons.

If one wishes to attribute the difference in the scattering to a difference in mass of both groups of particles, he can use the following approach. From the curve ψ_1 one can compute scattering curves corresponding to different masses, m, by the use of the approximate relation $\psi_m \propto 1/(pv)$ and compare the distribution of the individual scattering angles of the electrons about their least-squares curve ψ_1 with the distribution of the individual scattering angles of the positive tracks about the curves ψ_m corresponding to different masses. If a^2 is the ratio between an individual mean square angle $(\omega^2)_{Av}$ and a ψ_m^2 of the same momentum, then for $k^2 \geqslant 0$ we have plotted in Fig. 2 the number of particles (in percent) for which $a^2 \geqslant k^2$, as a function of k^2. The dashed curve A gives this cumulative distribution for the electrons about ψ_1 and the solid curves B, C, and D the distributions for the positive tracks about ψ_1, $\psi_{1.5}$, ψ_2, and $\psi_{2.5}$ corresponding to 1, 1.5, 2, and 2.5 electron masses. It can be seen that curve D agrees fairly well with curve A from which it follows that the individual root-mean-square scattering angles derived from the positive tracks are distributed about a scattering curve corresponding to mass two in a manner similar to that in which the root-mean-square scattering angles derived from electron tracks are distributed about a scattering curve corresponding to mass one. It should be mentioned in this connection that Smith and Groetzinger[3,11] have derived previously a mass of 1.5 to 2 electron masses for the particles producing the positive tracks from their momentum loss in a foil.

Two further results of some rather extensive investigations to be published later will be mentioned here briefly. It can be shown that it is extremely unlikely that any one of the observed positive tracks of a length exceeding 5 cm and an ionization smaller than five times the minimum ionization is, under the conditions used in our investigations, due to one of the decay electrons of P^{32}

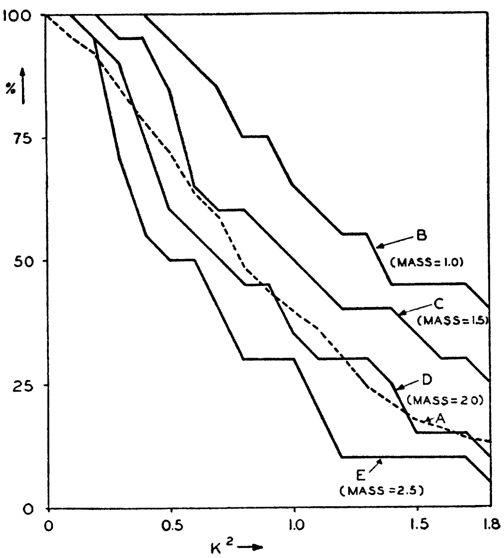

FIG. 2. Cumulative distribution of the mean-square scattering angles of 104 electrons about their least-squares curve (curve A), cumulative distributions of the mean-square scattering angles of 20 "positive tracks" about the least-squares scattering curve for the electrons (curve B) and about curves corresponding to 1.5, 2, and 2.5 electron masses (curves C, D, and E).

multiply scattered in a direction opposite to that which would occur under the influence of the magnetic field alone. Moreover this improbability already follows from the momentum spectrum of the positive tracks, which was investigated by many observers and which shows that the majority of these tracks have a considerable "positive" curvature, while tracks of a slight curvature are seldom observed. It was found by us on the other hand that, depending on the geometry and the method of investigating these tracks, the number of electrons re-entering the source might be appreciable, but that the number of these spurious positives can be reduced by proper source arrangement and a stereoscopic investigation of the tracks. With these precautions it was found to amount to not more than a few percent in our investigations.

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The Absorption of Penetrating Cosmic Rays Underground*

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AT a depth of 850 m.w.e. (8.5×10^4 g/cm²) in a salt mine, the absorption of the penetrating component in lead was determined by means of coincidences between two trays of G-M counters separated vertically by 100 cm. Each tray contained 10 cylindrical counters which were one inch in diameter, 30 inches long, and had $\frac{1}{32}$-inch brass walls. A count was recorded when one or more counters in the upper tray fired in coincidence with one or more in the lower tray. The lead absorber was placed between the two trays. The data are shown in Table I. The correction for coincidences due to gamma-rays is negligible,[1] the number of electrons capable of penetrating either thickness of absorber is negligible,[1] and the counter tray separation was the same for both absorber thicknesses. The counting rate was reduced by a factor of 0.94±0.06 when the thick absorber was added.

TABLE I. Absorption in lead of the penetrating component of cosmic rays.

Lead thickness	Time	Counts	Accidentals	Rate
11.4 cm	589 hr.	1228	116	2.08±0.06 hr⁻¹.
95 cm	144 hr.	297	15	1.95±0.12 hr.⁻¹

If the penetrating particles observed in the mine have penetrated the total thickness of earth above the mine (i.e., if the penetrating particles are not produced locally), it is to be expected that the absorption by lead between the counters would be the same as the absorption by an equivalent amount of earth above the counters. The absorption by an equivalent amount of earth can be obtained from the depth-intensity measurements of Wilson.[2] Thus the fractional reduction in intensity is expected to be

$$\frac{\Delta I}{I}=\frac{\gamma\Delta h}{h}=2.7\frac{84\times11.3\times82/207}{8.5\times10^4\times1/2}=0.024,$$

where $\gamma=2.7$ is the slope of Wilson's log depth-log intensity curve at $h=850$ m.w.e. and Δh is the change in thickness of absorber between the counter trays.

Since the attenuation of the penetrating-particle flux is independent of the position of the absorber within the uncertainty of the experiment, it is unlikely that any appreciable fraction of the penetrating particles is produced locally. This result is in marked contrast with the absorption reported by Miyazaki[3] at 3000 m.w.e. and by Barnóthy and Forro[4] at 1000 m.w.e. who report much larger decreases in counting rates with absorbers of about 90 cm of lead, *viz.*, about 70 percent and 30 percent respectively.

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Internal Conversion Coefficients of Sc^{46}

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THE gamma-rays following the 0.36-Mev beta-spectrum of Sc^{46} have been investigated as a further test of the theories of internal conversion which have been published recently.[1,2] The upper limit to the abundance of the high energy beta-spectrum[3] (1.49 Mev) was determined to be 0.06 percent rather than 2 percent as previously reported.[3]

The measurements were made with a double-coil thin lens spectrometer using the method described briefly in a recent letter by the authors,[4] and more fully in a paper now in press. The Sc^{46} sources were obtained from a sample of high specific activity material obtained from the Oak Ridge National Laboratory, Union Carbide and Carbon Corporation. The strong sources used in the measurement of internal conversion lines were less than 0.30 mg/cm² average thickness, and the weak sources used to investigate the continuum were less than 0.012 mg/cm². All were mounted on LC-600 films of less than 30 μg/cm², and there was no indication of any line broadening due to source thickness.

The experimentally determined values for the conversion coefficients of K, L, and M shells (unresolved), together with the theoretical[1] conversion coefficients for electric quadrupole radiation and magnetic dipole radiation in the K shell, are given in Table I. Assuming that the theoretical K value should be increased