



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 $\frac{3}{8}$ -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

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 .

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.

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

$$\frac{\Delta I}{I} = \frac{\gamma \Delta h}{h} = 2.7 \frac{84 \times 11.3 \times 82 / 207}{8.5 \times 10^4 \times 1/2} = 0.024,$$

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 Miyazaki³ at 3000 m.w.e. and by Barnóthy and Forro⁴ 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 Sc⁴⁶

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THE gamma-rays following the 0.36-Mev beta-spectrum of Sc⁴⁶ 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-spectrum³ (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 Sc⁴⁶ 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 μ g/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 theoretical¹ 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

TABLE I. Theoretical conversion coefficients in the K shell and experimental values for $K+L+M$ conversion for Sc^{46} .

E_{Mev}	$\alpha_{\text{exp}} \times 10^4$	Theoretical values	
		$E. O. \alpha_K \times 10^4$	$M. D. \alpha_K \times 10^4$
0.88	1.74 ± 0.08	1.51	1.10
1.12	0.98 ± 0.05	0.841	0.686

approximately ten percent to correct for the contribution of L plus M internal conversion and screening, the results classify both gamma-radiations as electric quadrupole. The predicted values for other types of radiations differ by a minimum factor of 1.6 from the experimental values. This result, together with those of recent angular correlation⁵ and polarization correlation experiments,⁶ fixes the spins and parities of the nuclear levels of $^{22}\text{Ti}^{48}$ as 0, 2, 4; same.

Previously reported values³ of the internal conversion coefficients for Sc^{46} required the radiations to be of a higher multipole order which is in disagreement with the angular correlation results^{5, 6} and lifetime considerations. The present results appear to remove this inconsistency.

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On the Theory of Supersonic Absorption

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SUPERSONIC absorption in liquids is larger than the value which follows from the constants of the continuum theory.¹ This indicates that there is a component $\alpha_{\text{rel}} = \alpha_{\text{exp}} - \alpha_{\text{cont}}$ which is due to relaxation in reaching thermodynamic equilibrium, displaced by acoustic waves. In addition to the relaxation of the intramolecular degrees of freedom² observed in gases, one can expect a structure dependent relaxation in liquids.^{3,4} We can show that, by considering a liquid as a quasicrystalline structure, one gets an absorption which corresponds roughly to the observed value for many liquids. Relaxation absorption is given by the expression

$$\alpha_{\text{rel}} = 2\pi^2 \rho c \nu^2 \kappa_i \tau, \quad \nu \ll 1/\tau, \quad (1)$$

where c = velocity of sound, ρ = density, ν = frequency. κ_i is the contribution to the total compressibility of the degree of freedom producing the relaxation. The relaxation time τ is a measure of the time required for achieving equilibrium after a sudden displacement from equilibrium, and can be determined from the reaction kinetics of the excitation process. If the concentration N of the excited state is small, τ is proportional to the lifetime of the excited state. If, therefore, the reverse reaction is a second or higher order process, τ is large.

We characterize kinetic effects in liquids such as viscosity, diffusion, and thermal diffusion⁵ by the rate, j , with which a molecule displaces its position on the average with respect to its neighbors. These processes presuppose a partial dissociation of the crystal structure, so that the long range order is destroyed by perturbations, i.e., holes. In a regular crystal these can only arise at the expense of a complementary perturbation, and they wander independently through the crystal by a shifting of position of the participating molecules. Creation and destruction of holes cannot follow directly the rapid compressions of sound waves, because a rearrangement within the crystal is necessary which can be

described by the fusion of two complementary disturbances. In the usual empirical expression,^{5, 6}

$$j = j_0 \exp(-q/RT); \quad (2)$$

the activation energy for position displacement therefore includes a part q_L , whose activation is determined by second-order reaction equations. It follows from the reaction kinetics of the creation and wandering of the holes that the lifetime and, therefore, the relaxation time of the holes is proportional to $1/j$ and can consequently be expressed in terms of the viscosity. One obtains:

$$\tau = V\eta/2RT, \quad (3)$$

where V is the molar volume. The values of τ are of the order of 10^{-11} sec.

In the isothermal approximation the part κ_i of the compressibility of the holes can be estimated from the hole energy q_L , which determines the concentration of the holes, and the average additional volume v , which follows from the pressure dependence of viscosity:

$$\kappa_i = \frac{v}{V} \frac{dN}{dp} = \frac{v}{V} \frac{v}{RT} \exp(-q_L/RT) = \frac{RT}{V} \left(\frac{d \ln \eta}{dp} \right)^2 \exp(-q_L/RT). \quad (4)$$

It can be shown that an additional temperature wave due to the adiabatic character of the sound wave yields at most terms of the same order.

Equations (1) to (3) relate the structure absorption α_{rel} to independently observable quantities and to q_L . There are good reasons for believing that the hole energy q_L is an appreciable fraction of the displacement energy q . The ratio of q_L to q_W , the heat of evaporation, is considered to be roughly equal to the ratio of the hole volume v to the molecular volume V . In Table I,

TABLE I. Data for structural absorption of liquids for high frequencies ($\nu > 10^7$ sec.⁻¹).

	$\left(\frac{\alpha_{\text{rel}}}{\nu^2}\right)_{\text{obs}}$	q_L kcal./mole ^a	q kcal./mole ^b	q_L/q_W	v/V^c
Acetone	24	0.9	1.8	0.12	0.21
Ethyl acetate	30	1.1	2.5	0.12	0.17
Ethyl alcohol	32	1.2	3.9	0.12	0.21
Ethyl bromide	52	0.7	2.1	0.11	0.19
Ethyl iodide	30	1.4	2.2	0.20	0.17
Acetic acid	127	0.7	2.6	0.10	(0.20)
Glycerol	<300	>3	14	>0.15	0.21
Heptane	70	0.7	2.4	0.08	0.14
Propyl alcohol	35	2.0	4.2	0.20	0.23
Oxygen	3	0.47	—	0.29	(0.1)
Argon	2	0.55	—	0.33	(0.1)
Mercury	1	1.6	1.2	0.10	0.04
Benzene	870	—	3.0	—	0.22
Toluene	75	0.8	2.6	0.09	0.16
Xylene	62	1.0	2.6	0.10	0.15

^a q_L is derived from $(\alpha_{\text{rel}})_{\text{obs}}$ by Eqs. (1) to (3).

^b q from temperature dependence of viscosity.

^c Interpolated values in brackets.

q_L is calculated on the assumption that α_{rel} is due entirely to structure and its value is compared with the above-mentioned quantities. There is agreement for many monoatomic and molecular liquids.

Other types of liquids with more complicated but symmetrical molecules, e.g., C_6H_6 , CCl_4 , possess a much larger absorption, which, however, decreases appreciably if some intramolecular substitutions [$\text{C}_6\text{H}_6 \rightarrow \text{C}_6\text{H}_5\text{CH}_3 \rightarrow \text{C}_6\text{H}_4(\text{CH}_3)_2$] are made that hardly affect intermolecular quantities such as viscosity. We assume that in these cases intramolecular relaxation degrees of freedom predominate, whose relaxation time is large in the symmetrical molecules.

Higher order reactions can be considered to be responsible for the much larger relaxation times ($\tau \sim 10^{-8}$ sec.) of some liquids. In this way, Lamb and Pinkerton⁷ explain the absorption of acetic acid as due to the dissociation of the acetic acid double molecule bound by H -bridges. Using our method, we deduce a binding