and copper sulfide. The first column purification removed a great deal of activity and the second removed a small amount in addition, whereas after the third purification the activity was unchanged. This residual activity, 54±1 counts per minute for a 10-gram sample spread over 1650 cm^2, is thus attributable to lanthanum.

An aluminum absorption curve was obtained with aluminum foils rolled inside the sample foil. Because of the considerable activity of the aluminum (5 to 80 counts/min), a separate background count had to be taken with each absorber over a bare copper sheet. From the differences, curve A of Fig. 1 was obtained. This shows a hard component, which was fitted with a theoretical absorption curve[6] for Ba K x-rays in 50 percent geometry, curve B. This extrapolates to 10 counts/min at zero absorber, but since about 2 counts/min are expected from the gamma-radiation,[4] we ascribe 8 counts/min to K x-radiation. We estimate our counting yield for these x-rays to be 1.5 percent, giving a specific activity of 1.0 K x-rays per second per gram of lanthanum. This is somewhat greater than the value 0.4 reported previously[4] and, if correct, would indicate appreciable electron capture to the ground state of Ba^{138}.

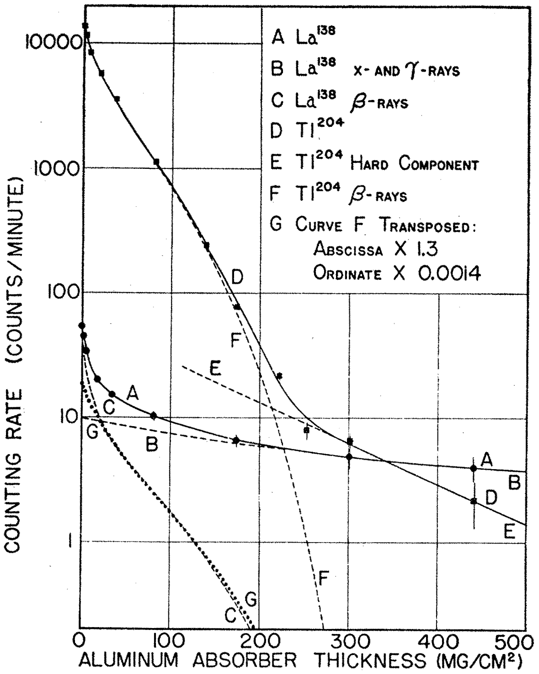

FIG. 1. La^{138} absorption curve and its analysis.

Curve C, the activity remaining after subtraction of the hard component, indicates an energetic beta-radiation. For a comparison analysis absorption measurements were taken under identical conditions on Tl^{204} mixed with pure Nd$_2$O$_3$, giving curve D. Subtraction of the weak hard component E leaves curve F with a range of 300 mg/cm^2. It was found that curve F could be fitted to curve C beyond about 30 mg/cm^2 by multiplying its abscissa by 1.3 and its ordinate by a suitable factor, giving curve G. Thus we take the range of the La^{138} particles to be $1.3\times 300=390$ mg/cm^2, corresponding to a maximum energy of 1.0±0.2 Mev. The extrapolated intensity for zero absorber is 19 counts/min. From the estimated counting yield of about 53 percent, the specific beta-activity is 0.07 particle per second per gram lanthanum. Their intensity relative to the γ-rays is too high for conversion electrons without isomerism, which is never observed in even-even nuclides. Their intensity relative to the x-rays is probably too high for positrons, and it would be difficult to reconcile the observed gamma-spectrum[4, 7] with annihilation radiation of the requisite intensity. Thus, we believe they are negative beta-particles. The excess radiations below 30 mg/cm^2 are probably compounded of L x-rays, K Auger electrons, and background enhancement,[1] although a weak soft beta-component may also be present.

Assuming a fluorescence yield of 86 percent for barium[8] and neglecting L-capture, we calculate an electron-capture partial half-life of 7×10^{10} years and a negatron partial half-life of 1.2×10^{12} years. The net half-life is essentially the same as for electron capture. The logft for the β^- transition is 21.3, which seems consistent with a fourth-forbidden transition from $_{57}\mathrm{La}_{81}{}^{138}$ in a $g_{7/2}-d_{3/2}$ configuration with spin 5 and even parity.

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Ionization Loss at Relativistic Velocities in Nuclear Emulsions*

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SINCE 1949, when nuclear emulsions sensitive to particles at minimum ionization became available, conflicting results have been reported on the variation in I, the rate of energy loss by ionization with velocity in the emulsion, as measured by grain density g at total energies $\gamma>4$ rest mass units.[1–8] Analysis of important high energy phenomena requires a knowledge of this variation; yet the very existence of a relativistic rise in g above its minimum value $g_{\min}$ has been controversial. Ionization theories predict a minimum rate of loss $I_{\min}$ at $\gamma\approx 4$, and a rise in I with increasing energy to a limiting value determined by the polarization of the medium.[9–11] The saturation of I sets in at different energies in the various theories (e.g., $20<\gamma<100$ in iron), but Fermi's plateau value I_{pl} remains essentially unaltered in the multifrequency theories of Wick and of Halpern and Hall.

In calibrating a set of 400 micron Ilford G.5 emulsions exposed to the cosmic radiation at an altitude of 100,000 ft, we have found evidence for a relativistic rise in I and measured its magnitude in the following way. In plates from the same batch, exposed and developed[12] together, a preliminary value $g_{\min}'$ was first obtained. Then g was measured for two groups of tracks: (a) thin shower tracks ("s tracks" with $g<1.25\ g_{\min}'$) emerging from nuclear explosions; each was $>2000\mu$ long, and contained 400 to 1400 grains; and (b) "p tracks," provisionally attributable to incident star-producing particles, i.e., thin upper-hemisphere tracks approximately collinear with the shower axis. These were required to have an associated shower multiplicity $n_s\geq 5$, and a length $>500\mu$. (The s tracks were not restricted in multiplicity; they originated in stars with $n_s\geq 1$.) Altogether, some 10^5 Ag grains were counted in this study.

Figure 1 shows our experimental frequency distribution in g for 43 s tracks and 48 p tracks. We shall show that the former group can be used for precise evaluation of $g_{\min}$, and the latter for estimation of g_{pl}, the "plateau" grain density corresponding to I_{pl}. Since g is proportional to I at low grain densities,[2, 12] the observed g_{pl} and $g_{\min}$ determine at once the ratio $I_{\mathrm{pl}}/I_{\min}$ in AgBr.

The s tracks are known to be due predominantly to pions.[2, 13] We have used their energy spectrum[13] and ionization theory[10] to calculate their expected distribution in ionization in the region

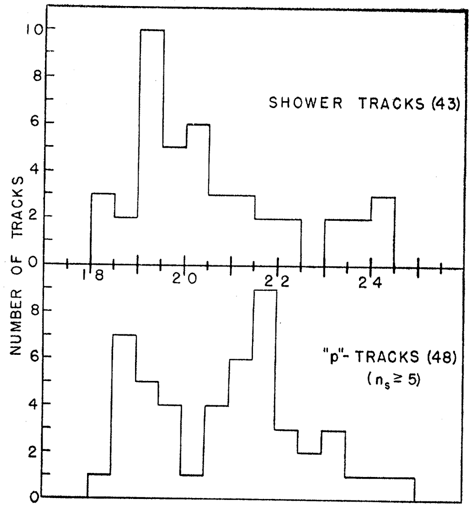

FIG. 1. Histograms showing frequency distributions in grain density of 43 *s*-tracks and 48 *p*-tracks. The peak of the former group determines $g_{\min}$, and the right peak of the latter group is interpreted as corresponding to g_{pl}.

$1.0 < I/I_{\min} < 1.10$. The calculated maximum of the distribution lies at $I_{\min}$ to within 1 percent—a result which is insensitive to the choice of ionization theory. The pions responsible for this peak are in the range $3 < \gamma < 6$.

The *p*-track histogram has a principal peak, at $21 < g < 22$, clearly displaced from that of the *s* tracks. We believe that this peak is due mainly to incident protons so energetic that their *g*-values lie at or very near g_{pl}. This view is supported by order-of-magnitude estimates of the proton energies γ, deduced from their associated multiplicities n_s, by applying Fermi's statistical theory of pion production.[14] At sufficiently high energies ($\gamma > 100$), this theory predicts $\gamma = (\bar{n}_s/1.2)^4$ for single nucleon-nucleon collisions. Substitution of our observed values of n_s in this formula would lead to gross overestimates of γ, since our *s* particles result from plural as well as multiple production. We have tried to correct for the effect of pluro-multiple production by employing a "reduced" $n_s' = n_s/2$. The resulting energy values will be 1/16th as large as those obtained from the observed n_s. Table I gives the numbers of observed *p* tracks with various n_s.

TABLE I. Distribution of *p* tracks according to their associated multiplicities n_s.

n_s	5	6	7	8	9	10–14
No. of *p* tracks	8	11	8	3	7	11

For 44 percent of the *p* tracks, $8 \leq n_s \leq 14$, the "reduced multiplicities" are $4 \leq n_s' \leq 7$, and the energies are $\approx 10^2 < \gamma < 10^3$. These energies (lower by a factor 16 than those calculated for pure multiple production) are still high enough so that the ionization of the corresponding *p* tracks should lie at or near the plateau. Hence, it seems reasonable to associate the main *p*-track peak with g_{pl}. About two-thirds of the *p* tracks cluster around this peak. The remaining one-third contribute to a second peak, close to $g_{\min}$. These may be due to (a) lower energy protons which generate showers by plural production alone, and (b) pions ejected upwards and misidentified as incoming particles.

In Fig. 2 we have plotted the grain-density data in a manner which should yield improved resolution in *g* and hence, more precise determination of $g_{\min}$ and g_{pl} than that obtainable from a simple block diagram, like that in Fig. 1. Since the *g* values of the tracks had various standard errors Δg based on their respective grain counts, we have constructed the histograms so as to give maximum weight to the most probable value of *g* for each track, and proportionately lower weights to the neighboring values. For each track we constructed a "triangle" whose base is proportional to Δg and whose height was determined by normalizing the triangle areas. Each triangle was centered at the appropriate *g* interval. Then, for each interval, the contributions from all the triangles which overlapped into it were added up. Each ordinate is thus determined not only by the tracks centered in a given interval, but also by the lesser contributions from other tracks whose best value of *g* lies nearby.

After correcting *g* values by -0.4 grain/100μ for background, we obtain

$$g_{\mathrm{pl}}/g_{\min} = (21.2_{-0.5}^{+0.7})/(19.0 \pm 0.4) = 1.12_{-0.03}^{+0.04}.$$

Preliminary investigation of energetic electrons ($\gamma > 300$, as determined from their multiple scattering) indicates that g_{pl} for electrons lies 16 ± 3 percent above $g_{\min}$ for mesons.

For comparison we have computed $I_{\mathrm{pl}}/I_{\min}$ for AgBr according to the theory of Halpern and Hall,[10] using for the average ionization potential, however, the value $13.5 \times (47+35)/2 = 554$ ev (lacking a better value for AgBr). Considering only transfers ≤ 5 kev to electrons,[4] the calculated $I_{\mathrm{pl}}/I_{\min}$ is 1.14. If the actual value of the ionization potential differs by as much as 20 percent from the one used here, the calculated ratio will differ by < 4 percent from 1.14.

Our results on mesons and protons suggest that the rate of ionization loss in nuclear emulsions at energies $\gamma > 4$ rises to a saturation value which lies 12_{-3}^{+4} percent above $I_{\min}$. These results are in substantial agreement with those of Pickup and Voyvodic[3] and Voyvodic.[15] However, if our tentative results for electrons should be confirmed, then our final estimate of $I_{\mathrm{pl}}/I_{\min}$ may be significantly higher than that of Voyvodic, who reports a rise of about 9 percent.

If the relativistic rise in ionization is altogether due to energy lost in the form of Čerenkov radiation[4,8] then one must assume

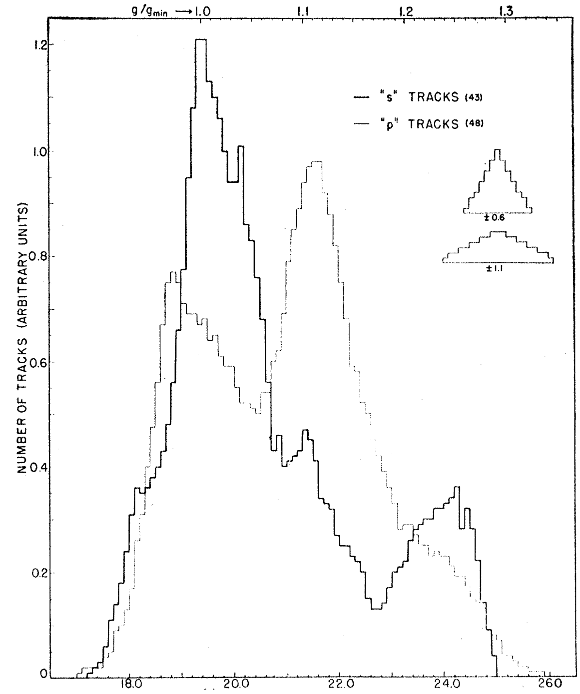

FIG. 2. The data of Fig. 1 have here been plotted in a manner which permits a somewhat more precise and less arbitrary determination of $g_{\min}$ and g_{pl} than that obtainable from a conventional block diagram. Each track was plotted as a triangle (like the two sample triangles shown) whose base is proportional to the standard error in *g*. Each ordinate was then determined by adding the contributions of all triangles which overlap into a given narrow interval in *g*.

that this radiation is almost entirely absorbed in traversing a grain of AgBr ($<1\mu$). This seems unlikely. A recent alternative explanation due to Schönberg[16] is that most of the relativistic increase arises from ionization and excitation.

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The Decay of Kr^{87}

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THE decay of 78-min Kr^{87} has not previously been studied β-spectrometrically. By absorption measurements on electromagnetically separated Kr^{87}, formed in fission, Koch *et al.*[1] found a maximum energy of the β-particles of 3.2 Mev.

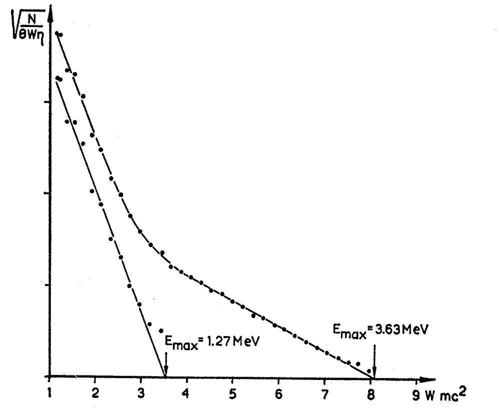

FIG. 1. Fermi plot of the β-continuum of Kr^{87}.

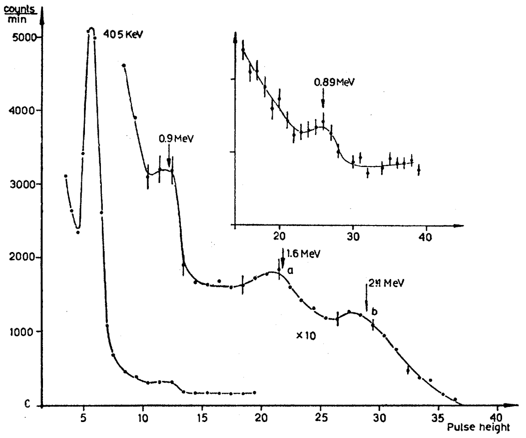

FIG. 2. Scintillation spectrum of Kr^{87}. The inset shows a separate measurement of the 0.89-Mev line.

In the present investigation Kr^{87} has been electromagnetically separated from other rare gas isotopes formed in uranium fission. The isotope of mass number 87 was collected on an Al foil of thickness 0.15 mg/cm^2. This foil was then used as a β-source in a magnetic lens spectrometer (resolution ~6 percent).

The β-continuum appears to be complex. The Fermi plot (Fig. 1) shows the presence of two β-components of energies 3.63 ± 0.07 and 1.27 ± 0.1 Mev, with relative intensities 75 percent and 25 percent, respectively. The values of log*ft* are found to be 7.3 (the Fermi plot having "not forbidden" form) and 5.9, respectively.

The scintillation spectrum of Kr^{87} (Fig. 2) shows the presence of a pronounced photopeak of a γ-ray of energy 405 ± 20 kev. The weak line at 0.89 Mev may be interpreted as the pair line of a γ-ray of energy 1.89 ± 0.07 Mev, the Compton peak of which appears at *a* (Fig. 2). The high energy peak *b* is most probably due to Compton quanta corresponding to a γ-ray of energy ~2.3 Mev. The scintillation spectrum ends at 2.6 Mev.

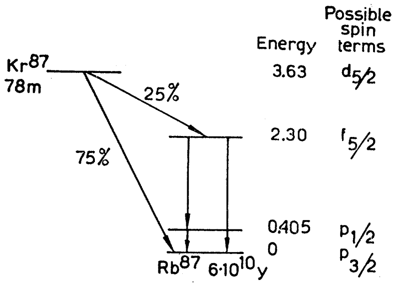

FIG. 3. Tentative decay scheme for Kr^{87}.

The data thus obtained can be accounted for by the decay scheme of Fig. 3. [Spin terms are given according to the strong spin orbit coupling theory.[2]] If this interpretation (Fig. 3) is correct, it is worth noting that the $f_{5/2}$ level is so far above the already filled $f_{7/2}$ level.

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