pletes essentially the investigations begun in 1948 for the purpose of studying the latitude effect of primary nuclei of charge $Z>1$. The flux values obtained in two separate flights near the magnetic equator agree well within statistical accuracy and are given by $I(\lambda=3°)=1.30\pm0.25$ particles/m^2 sec steradian for $6\leqslant Z\leqslant 10$, and $I(\lambda=3°)=0.30\pm0.07$ particles/m^2 sec steradian for $Z>10$.

Previously[2] it has been shown that all primaries arrive from outer space completely stripped of orbital electrons and that, therefore, the flux values at different latitudes permit the construction of an integral energy spectrum for the various components. The flux values obtained at the equator are in good agreement with the energy spectrum given in reference 2.

Our knowledge of the spectrum in the energy region above geomagnetic cut-off energies is less complete both for the proton and the heavy components. However, the results of various recent investigations permit us to describe quite reliably the charge and energy dependence of primary particles up to about one hundred times the equatorial cut-off energy.

On the basis of Fermi's theory of meson production and the range spectrum of mesons below ground, Haber-Schaim[3] deduces an integral spectrum proportional to $\epsilon^{-1.56}$ for the total primary radiation in the energy interval $10^{11}<\epsilon<1.2\times10^{12}$ ev (ϵ is the energy per nucleon).

Independent support for this power law is obtained from the photographic emulsion technique applied to Auger showers.[4] Preliminary results[5] obtained with this technique indicate that the flux, not only of protons but also of primary helium nuclei, is in the energy interval $10^{10}<\epsilon<4\times10^{12}$ ev consistent with the power law exponent derived from observations on mesons.

Also heavy nuclei of charge $Z>10$ seem to follow the same power spectrum. This was verified up to energies of 5×10^{10} ev/per nucleon with the help of nuclear collisions.[2] Occasional observations on nuclei of still larger energies, however, make it certain that no drastic change in the exponent occurs up to about 5×10^{11} ev/nucleon.

Thus we are led to the conclusion that the chemical composition of the primary beam is essentially constant not only in the latitude sensitive region but even at much higher energies. The uniformity of composition holds at least over a factor 1000 in the energy per nucleon, a range of energies which comprises all but one part in ten thousand of the incoming primaries and at least 95 percent of the incident energy.

The incident cosmic-ray energy carried by various primary components is approximately distributed as follows:

66 percent due to protons;
26 percent due to helium nuclei;
5 percent due to carbon, nitrogen, and oxygen;
3 percent due to nuclei of atomic number $Z\geqslant10$.

It is important to note that this distribution, which has previously been obtained[6] for a much more restricted range of energies, has now been shown to be valid for the primaries which produce the bulk of cosmic radiation at sea level ($5\times10^{9}<\epsilon<5\times10^{11}$ ev/nucleon) and therefore represents also the relative contribution of different components to the sea level intensity. Thus, since the sea level intensity if corrected for barometric and temperature effects shows a variation with solar time of only about 0.3 percent and a variation with sidereal time of less than 0.02 percent,[7] it follows that even for the heaviest primary nuclei in this energy range the variation with solar time must be less than 10 percent and with sidereal time less than 1 percent.

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[1] A full description of these experiments, which were carried out jointly by the Tata Institute of Fundamental Research and the University of Rochester will be published elsewhere.

[2] Kaplon, Peters, Reynolds, and Ritson, Phys. Rev. **85**, 295 (1952).

[3] U. Haber-Schaim, Phys. Rev. **84**, 1199 (1951).

[4] Kaplon, Peters, and Ritson, Phys. Rev. **85**, 900 (1952).

[5] Kaplon, Ritson, and Woodruff, Phys. Rev. **85**, 933 (1952).

[6] B. Peters, *The Nature of Primary Cosmic Radiation* (North-Holland Publishing Company, 1952), Chapter IV, "Progress in Cosmic Ray Physics."

[7] H. Elliot, see reference 6, Chapter VIII.

Internal Conversion of the 0.411-Mev Gamma-Ray of Hg^{198}

Lennart Simons
Institute of Physics, University of Helsingfors, Helsingfors, Finland
(Reveived March 25, 1952)

ON the basis of the measured spectra of the beta- and gamma-rays of Au^{198} [1] the K, L, and M conversion coefficients of the 0.441-Mev gamma-ray were found with an accuracy better than one percent to be $\alpha_K=0.0318$; $\alpha_L=0.0103$; $\alpha_M=0.0031$. The values were obtained on the supposition of a one-to-one occurrence of a 0.965-Mev electron and a 0.411-Mev gamma-quantum. On the other hand, if one assumes according to Cavanagh[2] that in addition to the 0.965-Mev beta-ray the 0.29-Mev beta-ray (branching ratio 1.76 percent) is followed in part by the 0.411-Mev gamma-ray after a 0.67-Mev gamma-emission (branching ratio 1.43 percent), one obtains for the 0.411-Mev gamma-ray $\alpha_K=0.0307$. The vanishing intensity of the 1.37-Mev beta-ray has been neglected and the branching ratio of the K-capture transition to Pt^{198} has been estimated to be approximately five percent. Considering the accuracy of the measurements, this latter value of the K conversion coefficient for the 0.411-Mev gamma-ray of Hg^{198} agrees exceptionally well with the theoretical value, $\alpha_K=0.031$, obtained by interpolation of the coefficients calculated by Rose *et al.*[3] for electric quadrupole radiation. An agreement between theory and experiment has thus been established and one may unambiguously conclude that the 0.411 gamma-ray of Hg^{198} is a pure electric quadrupole radiation.

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[1] L. Simons and E. P. Tomlinson, Soc. Sci. Fenn. Comm. Phys. Math. XVI, 6 (1952).

[2] P. E. Cavanagh, Phys. Rev. **82**, 791 (1951).

[3] Rose, Goertzel, Spinrad, Harr, and Strong, Phys. Rev. **83**, 79 (1951).

Thermal Conductivity of Germanium

A. Grieco and H. C. Montgomery
Bell Telephone Laboratories, Murray Hill, New Jersey
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A MEASUREMENT has been made of the thermal conductivity of high purity, single-crystal germanium, made by the method of Teal and Little.[1] Conductivity was determined from the relative temperature drops along rods of germanium and some material of known conductivity, placed thermally in series. Nickel and cast zinc of high purity were used for the comparison materials. With precautions taken to minimize errors from heat losses, it is believed the measurements are accurate to better than ±10 percent.

The germanium specimen was cut from a single crystal of n-type material of resistivity about ten ohm-cm. Its dimensions were 5/16 inch square cross section by 3/4 inch long, with the long dimension oriented along a 100 crystal axis. The thermal conductivity was found to be 0.14 cal/sec cm °C at 25°C, and roughly 20 percent less at 100°C.

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[1] G. K. Teal and J. B. Little, Phys. Rev. **78**, 647 (1950).

Short Duration Afterglow of Nitrogen in the Photographic Infrared

R. Herman, L. Herman, and G. Hepner
Observatoire de Meudon, Meudon (Seine et Oise), France and Laboratoire des Recherches Physiques, Sorbonne, Paris, France
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KAPLAN[1] was the first to study the afterglow of long duration (0.1 to 1 sec) which produces the first negative band system, $B^2\Sigma-X^2\Sigma$, of N_2^+. A short duration afterglow (10^{-4} to 10^{-2} sec) emitting the same band system has been described by us elsewhere.[2] The present note is concerned with an extension of

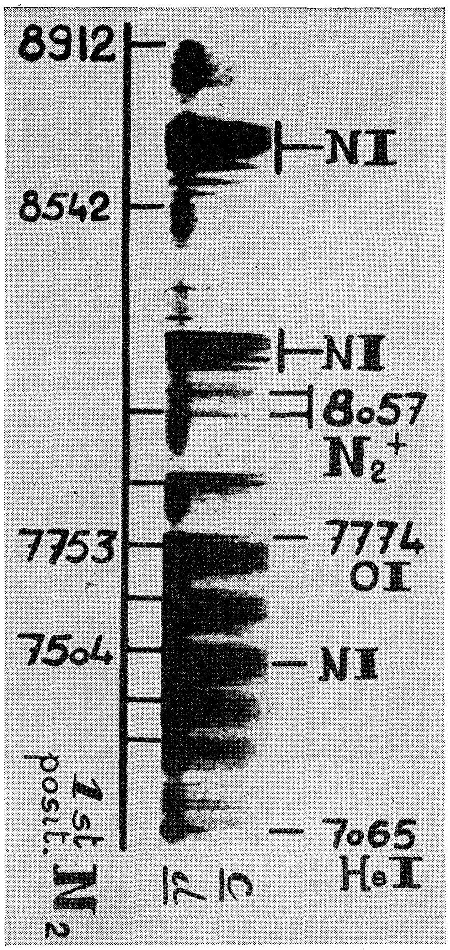

FIG. 1. Emission spectrum of a helium-nitrogen gas mixture. *d*-discharge spectrum. *c*-afterglow spectrum. In *d*, the 7065 He I line and the first positive system $B^3\Pi-A^3\Sigma$ of N_2 are very strong. In *c*, the 8057 band of N_2^+ is clearly visible.

our short duration afterglow studies into the photographic infrared.

A pulse discharge was used to excite a mixture of helium, at a pressure of 5 mm, and a small amount of nitrogen. The spectra of the discharge and the afterglow were separated by a rotating disk.

An example of the spectrum obtained is shown in Fig. 1. Part *d* of this spectrum is emitted during the discharge and part *c* during about 10^{-4} second immediately after the discharge is stopped. It is seen that relative intensities of the several spectral features are quite different in the afterglow from those in the discharge proper. The apparent electronic excitation during the discharge is much lower than during the afterglow. For example, the first positive band system, $B^3\Pi-A^3\Sigma$ ($T_e=7.4$ ev), is strong in *d* and weak in *c*. In the violet and ultraviolet region, the second positive band system, $C^3\Pi-B^3\Pi$ ($T_e=11.0$ ev) of N_2, is also very weak in the afterglow spectrum. On the other hand, high level emissions, such as the Meinel system of N_2^+, $A^2\Pi-X^2\Sigma$, ($T_e=16.8$ ev) and the N I (I.P.$=14.54$ ev), N II (I.P.$=44.14$ ev), and O I (I.P.$=13.61$ ev) lines show a much smaller contrast between the discharge and the afterglow intensities. In the negative system of N_2^+ emitted during the afterglow the intensity of the 8057 (3, 1) band is higher than the 7828 (2, 0). On the other hand, in the auroral spectrum the (2, 0) band is the more intense.

The present results indicate that the process of excitation of the positive bands is different from that of the negative bands and atomic lines. These latter may be emitted by ion electron recombination, a process which becomes relatively more important during the afterglow.

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[2] R. Herman and L. Herman, J. phys. et radium (VIII) **10**, 132 (1949).

498-kev Gamma-Ray of Ru^{103}

ARTHUR W. KNUDSEN
Nucleonics Division, Naval Research Laboratory, Washington, D. C.
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AN accurate value for the energy of the 498-kev gamma-ray from Ru^{103} has been obtained with a double-focusing beta-spectrometer of the type described by Kurie, Osaba, and Slack.[1] The gamma-ray source was double, consisting of pile-irradiated ruthenium powder sealed in a glass tube and a metal enclosure (beryllium) providing annihilation quanta from the positron-emitting sodium-22 contained inside. Gammas from the two sources simultaneously irradiated a 0.7-mil thick uranium foil radiator, and the *K*-level photoelectric lines were recorded in the spectrometer. The difference in energy between the two lines (that of the annihilation gamma being the greater) was found to 13.1 ± 0.8 kev.

When the value 510.969 ± 0.010 kev given by DuMond and Cohen[2] for the energy of annihilation quanta is used, we obtain the value

$$497.9\pm0.8 \text{ kev}$$

for the energy of the ruthenium gamma-ray. A value of 494 kev (presumably for this same gamma-ray) has been given by Mei, Huddleston, and Mitchell.[3]

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[1] Kurie, Osaba, and Slack, Rev. Sci. Instr. **19**, 771 (1948).
[2] J. W. N. DuMond and E. R. Cohen, Phys. Rev. **82**, 555 (1951).
[3] Mei, Huddleston, and Mitchell, Phys. Rev. **79**, 237 (1950).

Pion Production and Charge Independence*

J. M. LUTTINGER
Department of Physics, University of Wisconsin, Madison, Wisconsin
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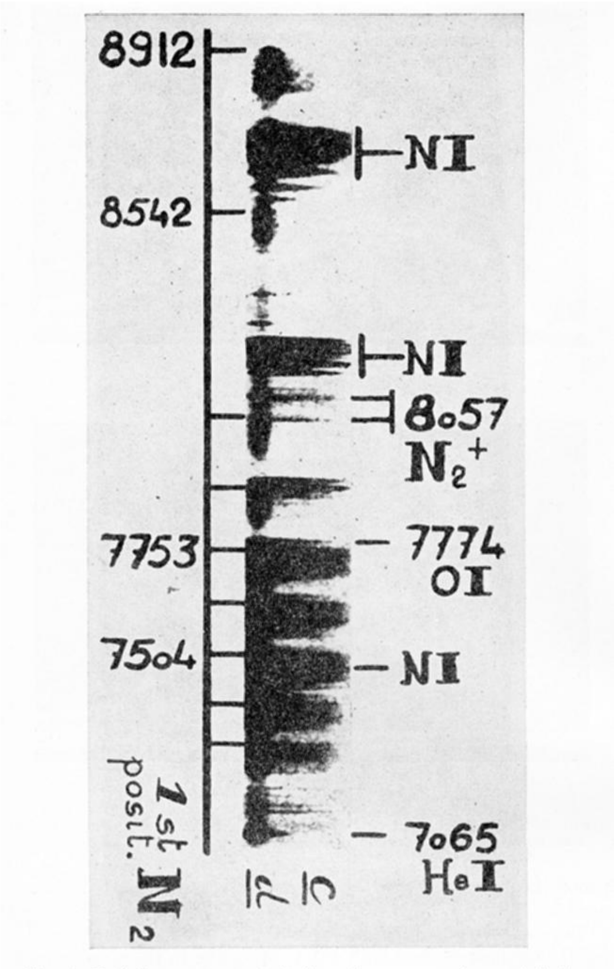
THE purpose of this letter is to point out that the observation of pion production in nucleon-nucleon and in nucleon-deuteron collisions provides a very severe test of the assumption that the interaction between pions and nucleons is charge independent. Just as we think of the proton-neutron field as having an intrinsic isotopic spin of $\frac{1}{2}$ ($+\frac{1}{2}$ for proton, $-\frac{1}{2}$ for neutron), we may also think of the meson field as having an intrinsic isotopic spin of 1 ($+1$ for π^+, 0 for π^0, -1 for π^-).[1] The assumption of charge independence will then mean that we assume the interaction to be such that the total isotopic spin is not changed as a result of it.

For simplicity let us consider first the case of meson production by proton (or neutron) collisions with deuterium. Since the deuteron is in a ${}^3S+{}^3D$ state, it is symmetric in space and spin and, therefore, antisymmetric in isotopic spin. The total isotopic spin of the deuteron is therefore zero. Thus, the system proton plus deuteron has total isotopic spin $T=\frac{1}{2}$, three component of total isotopic spin $T_3=\frac{1}{2}$. After the pion has been produced, the final state will consist of three nucleons and one pion. For the three nucleons, each with isotopic spin $\frac{1}{2}$, we get as possible states $T^N=\frac{3}{2}$ or $\frac{1}{2}$. This gives us two cases to consider:

1. Final nucleon state $T^N=\frac{3}{2}$. Using the well-known transformation properties of angular momenta,[2] we may write for the final state (*t* denoting the isotopic spin of the meson)

$$\begin{aligned}\phi(T=\tfrac{1}{2}, T_3=\tfrac{1}{2})=(1/\sqrt{2})\Psi(T_3^N=\tfrac{3}{2}, t_3=-1)\\ -(1/\sqrt{3})\Psi(T_3^N=\tfrac{1}{2}, t_3=0)+(1/\sqrt{6})\Psi(T_3^N=-\tfrac{1}{2}, t_3=1).\end{aligned}$$



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