only a fraction of the coefficients of the electron density series can be determined in this way. The fraction is $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, or 1, corresponding, respectively, to the implication ambiguity of 4, 3, 2, and 1. Therefore, if an electron density map is computed using the terms whose coefficients are determined in this manner, n possible positions appear for each atom in the crystal structure, where n is the ambiguity coefficient of the implication. The wrong positions can only be removed by supplying the electron density series with the missing terms.

[1] M. J. Buerger, "The interpretation of Harker syntheses," J. App. Phys. 17, 579–595 (1946).
[2] M. J. Buerger, "The solution of ambiguities arising in crystal structure analysis," Am. Soc. for X-Ray and Elec. Diff., abstracts of papers given at the 1947 summer meeting, Ste. Marguerite Station, Quebec, pp. 21–23.

The East-West Asymmetry of the Hard Component of the Cosmic Radiation*

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March 3, 1948

THE east-west asymmetry of the total cosmic radiation at altitudes above 5 cm Hg was found by Johnson[1] to be only about 7 percent. From this it was concluded that the primary radiation consisted of nearly equal numbers of positive and negative particles. On the basis of the experiments of Schein, Jesse, and Wollan,[2] it was proposed in 1941 that the majority of the primaries consist of protons. Arley,[3] combining these ideas, suggested that the primaries consist of equal numbers of positive and negative protons. To test whether or not most of the hard component, which has a small asymmetry at sea level, is actually produced by positive primaries, we measured the east-west asymmetry of particles penetrating more than 22 cm of Pb over a considerable latitude range at a high altitude.

The counter telescopes were mounted in a B-29 airplane in such a way that the zenith angle could be adjusted. In flight, the plane flew back and forth over the same course, with each telescope pointing alternately to the east and to the west so as to average out any systematic differences in their counting rates. The counters were connected both in threefold and in fourfold coincidence. However, only the fourfold data were used here in computing the asymmetry. An estimate of the correction required for the shower counting rate was obtained by counting the showers which tripped four counters with one counter moved out of line. The asymmetry was corrected by using this value of the shower rate. According to Johnson,[4] the showers show no asymmetry. A shower counting rate higher than that actually observed would decrease the observed value of the asymmetry. Dead time and resolving time measurements were made and the single counting rates of the counters were checked in flight. Errors in the asymmetry due to these causes were found to be negligible. The ground counting rate was determined between flights as a check on the operation of the equipment.

Flights were made between the geomagnetic latitudes of 27° 18′ North and 58° 30′ North with the telescopes at a 45° zenith angle. The results are shown in Table I. The asymmetry increases from a low value at the northern end to a value of over 45 percent at the southern end of the flights.

A flight was made to 27° 30′ North geomagnetic latitude to explore the effect at other zenith angles. The telescopes were at a zenith angle of 60° on the way south and at 30° on the way back. The results are given in Table II.

Table II shows that the east-west asymmetry undergoes large fluctuations with zenith angle at a latitude near 33° North. This effect is of considerable interest in connection with the problem of the primary radiation. It is planned to continue these measurements in the near future.

The latitude effect of mesotrons passing through 21 cm of Pb as a function of altitude was measured by Gill, Schein, and Yngve.[5] Using the observed value of the latitude effect, the large asymmetry of 46 percent detected for a zenith angle of 45° between latitudes of 27° and 32° is in general agreement with the theory of Lemaitre and Vallarta,[6] provided that all of the primaries which produce mesotrons of energies greater than about 6×10^{8} ev are positively charged. The lower limit of the mesotron energy is derived from the ionization loss in the atmosphere between the average height of their production[7] and the pressure altitude of 31,000 feet.

TABLE I. Latitude dependence of the east-west asymmetry at 45° zenith angle.

Geomagnetic latitude range	27° 18′ 32° 00′	31° 00′ 35° 40′	35° 00′ 40° 25′	39° 30′ 43° 00′	45° 00′ 50° 00′	50° 00′ 54° 00′	54° 00′ 58° 30′
Pressure altitude	34,500 ft.	32,000 ft.	31,000 ft.	37,000 ft.	31,000 ft.	31,000 ft.	31,000 ft.
East-west asymmetry $\frac{E_w-E_e}{1/2(E_w+E_e)}$	0.46±0.07	0.27±0.07	0.14±0.06	0.17±0.03	0.09±0.05	0.13±0.05	0.01±0.06

TABLE II. East-west asymmetry at 30° and 60° zenith angle for a pressure altitude of 31,000 feet.

Geomagnetic latitude range	27° 55′ 31° 05′	31° 05′ 35° 35′	35° 35′ 41° 00′	27° 30′ 32° 07′	32° 07′ 35° 35′	35° 35′ 40° 10′
Zenith angle	30°	30°	30°	60°	60°	60°
East-west asymmetry $\frac{E_w-E_e}{1/2(E_w+E_e)}$	0.4±0.1	−0.02±0.09	0.003±0.07	0.02±0.13	0.2±0.1	−0.06±0.1

We wish to thank the United States Navy and Army Air Force personnel at Inyokern, California for their cooperation in carrying out the airplane flights.

* This research was supported in part by Navy Contract N6ori-20, Task Order XVIII.

[1] T. H. Johnson and J. G. Barry, Phys. Rev. **56**, 219 (1939).
[2] Marcel Schein, W. P. Jesse, and E. O. Wollan, Phys. Rev. **59**, 615 (1941).
[3] N. Arley, Kgl. Danske Vid. Sels. Math.-Fys. Medd. **23**, 42 (1945); Physica **12**, 177 (1946).
[4] T. H. Johnson, Phys. Rev. **47**, 318 (1934).
[5] P. S. Gill, Marcel Schein, and V. H. Yngve, Phys. Rev. **72**, 733 (1947).
[6] G. Lemaitre and M. S. Vallarta, Phys. Rev. **49**, 719 (1936).
[7] Marcel Schein and J. Steinberger, Phys. Rev. **72**, 734 (1947).

Erratum: Natural Radioactivity of Rhenium

[Phys. Rev. **73**, 487 (1948)]

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THREE numbers in the recent article on the natural radioactivity of rhenium are erroneous. They are contained, respectively, in the last three paragraphs of the article, and in each case in the last sentence of the paragraph. The changes are, in order:

2.6×10^{12} years to be changed to 5.3×10^{12} years.
3.1 counts per minute to be changed to 31 counts per minute.
3×10^{12} years to be changed to 4×10^{12} years.

The Interactions of Nucleons with Meson Fields

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February 25, 1948

FOR a nucleon field Ψ interacting with a pseudoscalar field ψ there are available two forms of interaction, the pseudovector

$$H_1=g\int \Pi(\sigma\cdot\nabla\psi-(1/c)\gamma_5\pi)\Psi d\tau,$$

and the pseudoscalar

$$H_2=G\int \Pi\beta\gamma_5\psi\Psi d\tau.$$

These, and the corresponding two interactions with the scalar, the vector, and the pseudovector meson fields, were systematized by Kemmer.[1] Following Kemmer, several investigators have carried out calculations with the pseudoscalar field, using the interaction H_1 without the term in γ_5, justifying this procedure with the remark that the term in γ_5 in H_1 and the entire interaction H_2 would be negligible in problems concerning nucleons with non-relativistic velocities. That this argument is unsound Bethe[2] discovered by calculating nuclear potentials and scattering effects, using the complete interactions H_1 and H_2 in turn, and finding that either interaction gave the same form for these effects. Moreover, one can see directly that the matrix elements of $\nabla\psi$ for processes involving small momentum transfer are small, just as are those of γ_5, so that one may expect both parts of H_1 and H_2 to be of the same order of magnitude.

The purpose of this letter is to point out that the interactions H_1 and H_2 are, in fact, *completely equivalent for first-order radiative processes* and for many higher order processes as well. This fact was long ago noted by Nelson,[3] but it seems worth while to put forward the following derivation of the equivalence as in some ways more comprehensive than Nelson's. Let

$$H_0=\tfrac{1}{2}\int(\pi^2+c^2|\nabla\psi|^2+\mu^2c^2\psi^2)d\tau \\ -c\int\Pi(\alpha\cdot\nabla+iM\beta-V)\Psi d\tau$$

be the Hamiltonian of the meson field and the nuclear field with an external potential V, without interaction between the two fields. The total Hamiltonian $H=H_0+H_1$ may be transformed by a contact transformation to the form $H'=e^{iS}He^{-iS}$, with

$$S=-(g/\hbar c)\int\Pi\gamma_5\psi\Psi d\tau.$$

This transformation is a gauge transformation of conventional type, and after some reduction we obtain $H'=H_0+H_1'$, where

$$H_1'=c\int\Pi(iM\beta(1-e^{-2(g/c)\gamma_5\psi}))\Psi d\tau-\tfrac{1}{2}(g^2/c^2)\int(\Pi\gamma_5\Psi)^2d\tau.$$

The reason why the exponential survives in H_1' only in the term involving β is that γ_5 commutes with α and σ but not with β. The last term in H_1' represents a δ-function interaction (which has no physical meaning) between nucleons. Hence the interaction H_1 is equivalent to the first term of H_1' alone. Expanding the exponential, this gives (i) the interaction H_2 with $G=2iMg$ and (ii) higher order terms, most of which appear to be merely of the nature of "mass effects."[4]

In view of this result and the greater simplicity of the interaction H_2, it is recommended that H_2 be used exclusively in future calculations.

The same method may be used when the meson field is either *charged* or *symmetrical*; in this case, additional terms appear in H_1', but only of the second and higher orders in the meson field. Further, the result is true when V is either an ordinary or a spin-exchange potential, but not when V is a charge-exchange potential.

When ψ is a scalar field, there is the usual scalar form of interaction, and also a vector form

$$g\int\Pi(\alpha\cdot\nabla\psi+(1/c)\pi)\Psi d\tau.$$

Using a contact transformation with

$$S=(g/\hbar c)\int\Pi\psi\Psi d\tau,$$