The result of the canonical transformation shows on the other hand that there occurs an infinity of another type, a term containing electromagnetic potential bilinearly. Because of this structure this infinity is to be attributed to the vacuum polarization effect. In order to see the role to be played by this effect in collision phenomena we analyzed the infinities occurring in the e^2-correction to the Klein-Nishina formula.[13] In this problem, we found, besides the infinities of the types mentioned above, an infinity which is closely related to the above mentioned vacuum effect. Infinity of this kind can be, in fact, driven away from the cross section when we substract beforehand the infinite term of the vacuum type from the Hamiltonian. But for this subtraction we cannot find a reasoning so natural and plausible as that used in the case of mass-type and charge-type infinities, where the subtraction was considered as an amalgamation. This is because it would necessarily result in a drastic change of the Maxwell equation for the radiation.

A way out of this difficulty was suggested:[14] it might be possible to introduce some fields which would give rise to the vacuum effect with the opposite sign so that a compensation method similar to the f-field theory might be used here. In fact, one finds, applying the same method, that a Pauli-Weisskopf field has this property.[15] An alternative possibility is to consider, in the style of Dirac's theory of the classical electron, that the "original equation" for the radiation contained, in the same way as the "original mass" of the electron, in itself an infinity with the opposite sign so that, supplemented with the infinity appearing as the result of the interaction, the equation for the observable field becomes just of the Maxwellian form.

The calculation of the level-shift of a bound electron was also undertaken.[16] This work is not yet completed but it was confirmed that the result converges by virtue of our subtraction prescription. We found further, in agreement with Schwinger, that a part of the radiative correction to the energy can be interpreted as caused by an anomalous moment of the electron the existence of which had been expected by Breit.[17]

We hope that various postwar difficulties will soon be settled and that our results will appear in print in the near future.

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[15] K. Baba, M. Sasaki and R. Suzuki, to be published in Prog. Theor. Phys. It was first pointed out by Sakata and Umesawa in the Nagoya University that the Pauli-Weisskopf field gives rise to a positive self-energy of a photon in contrast to a negative one due to the electron field and this would result in the compensation of the vacuum effect mentioned above.
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Note on the Above Letter: In transmitting to the Physical Review the accompaning review by Tomonaga of the remarkable work carried out in Japan in recent years, there is one technical note that may be helpful.

Tomonaga remarks in the fifth paragraph from the end that in addition to the infinite terms which may be recognized as contributions to mass and charge, there are other infinities which appear, particularly in the corrections to the Klein-Nishina formula. These have to do with the familiar problem of the light quantum self-energy. As long experience and the recent discussions of Schwinger and others have shown, the very greatest care must be taken in evaluating such self-energies lest, instead of the zero value which they should have, they give non-gauge covariant, non-covariant, in general infinite results. From manuscripts kindly sent by Tomonaga, I would conclude that the difficulties referred to in this note result from an insufficiently cautious treatment, and therefore inadequate identification, of light quantum self-energies.

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The Absorption of Cosmic Radiation in Meteorites

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A PREVIOUS letter[1] showed that cosmic radiation has produced an appreciable amount of the helium found in metallic meteorites. Since the rate of helium production is directly proportional to the intensity of the cosmic radiation, the radial variation of this cosmic-ray helium within a spherical iron meteorite can be calculated from the radial variation in the intensity of primary cosmic radiation.

If N_0 and $N(r)$ are, respectively, the number of primary cosmic-ray particles passing through a unit sphere (cross

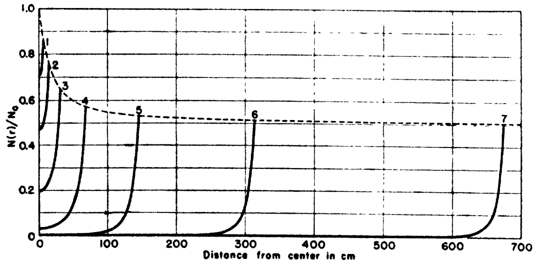

FIG. 1. The radial variation in the intensity of primary cosmic radiation (or in the relative helium content) in spherical iron meteorites of various masses. The numbers at the top of the curves are log mass in kg.

section = 1 cm²) per second in free space and at a point P at a distance r from the center of an iron sphere of radius R and density $\rho=7.8$ g/cc, then the relative intensity of primary cosmic radiation at P is,

$$\frac{N(r)}{N_0}=\frac{1}{4\pi}\int e^{-d/D}d\omega$$

$$=\frac{1}{4r}\int_{R-r}^{R+r}e^{-d/D}dd+\frac{R^2-r^2}{4r}\int_{R-r}^{R+r}(e^{-d/D}/d^2)dd.$$

D (19.2 cm for iron) is the distance in which a primary cosmic-ray particle will, on the average, produce one disruption, and d is the distance from P to a point on the surface of the iron sphere. Figure 1 shows the radial variation of $N(r)/N_0$ and thus also of the relative helium content of spherical iron meteorites of various masses. These results can be applied with considerable accuracy to metallic meteorites of any compact shape.

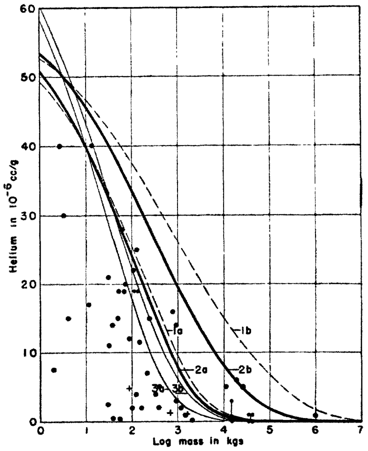

FIG. 2. The variation of the helium content with mass for metallic meteorites. The curves are drawn for the following assumptions for the ratio, m/M, of the final to the pre-atmospheric mass. $m/M=0.729$, curve 1a—center of meteorite, 1b—edge of meteorite; $m/M=0.512$, 2a—center, 2b—edge; $m/M=0.125$, 3a—center, 3b—edge. The points represent the helium content and mass of the meteorites measured by Paneth.

The curves of Fig. 2 show the calculated helium contents at the centers and at the edges of meteorites as a function of their masses. These curves are calculated on the assumptions that cosmic radiation has produced 4×10^{-5} cc of He/g at the center of a meteorite that has a final mass of about 10 kg (see the observed points in the mass-helium content diagram) and that cosmic radiation has acted on all meteorites for the same time, namely, the time since the disruption of their parent planet. The curves of Fig. 2 are drawn for three very different assumptions about the mass lost by the meteorite in traversing the earth's atmosphere, and show that the results are not greatly affected by the particular assumption that is made. The points of Fig. 2 are the helium contents of meteorites measured by Paneth[2] plotted against their masses. Significantly, the curves parallel the upper boundary of the observed points and thus account for the most important feature of the mass-helium content diagram. In addition, it is apparent that if cosmic radiation has produced the helium in small meteorites, then this process is sufficient to produce, in the same time, all of the helium observed in any meteorite.

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On the Origin of the Neutrons Associated with the Extensive Cosmic-Ray Showers

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June 4, 1948

IN a previous work evidence has been obtained of the presence of neutrons in the extensive cosmic-ray showers.[1]

We are now reporting preliminary results of further experiments performed at sea level in order to study the mechanism of production of those neutrons.

The same apparatus and the same technique of delayed coincidences between Geiger-Müller counters and BF_3 proportional counters, as described in reference 1, have been used.

Coincidences $S=a+b+c$ selected extensive showers, a, b, and c consisting of unshielded Geiger-Müller counters of 2000-cm² surface, arranged in a horizontal plane, at the vertices of a triangle of 4-m sides.

Neutrons were recorded by two identical detectors, N_1 and N_2, each consisting of four BF_3 counters imbedded in a paraffin box of 45×45×50 cm³ volume (counter surface 2.5×45 cm²).

Coincidences $S+N_1$ and $S+N_2$ indicated neutrons associated with extensive showers.

Incoherent neutrons N_1 and N_2 (i.e., neutrons not associated with extensive showers) were also simultaneously recorded, as well as coincidences N_1+N_2, not associated with extensive showers.

The experiments were performed by varying absorbers around absorber N_1. Detector N_2 was always kept far from any absorber, so that its constant rates provided a check of the regular running of the apparatus.

In Fig. 1 the arrangements of the absorbers around detector N_1 and the corresponding results are reported. Column 1 gives the rate $S+N_1$ of neutrons detected in N_1 associated with showers $S=a+b+c$. Column 2 gives the rate of incoherent neutrons in detector N_1, and column 3 the rate of coincidences N_1+N_2 between neutrons in detectors N_1 and N_2.

Tests with Cd shields around the BF_3 counters showed that the background caused by spurious phenomena was zero for both $S+N_1$ and N_1+N_2, while it was about 6 percent of the recorded rates for N_1.

Consider first the results for $S+N_1$, i.e., for neutrons associated with extensive showers: