TABLE I. Saturation of the ammonia (3,3) line in a rectangular guide.

Incident power Milliwatts	Relative saturation		
	Theoretical	Theoretical	Experimental (ref. 3)
2.7×10^{-4}	1.00	(1.00)	1.00
5.5×10^{-2}	0.89	(0.88)	0.82
5.5×10^{-1}	0.45	(0.43)	0.48
5.3	0.10	(0.08)	0.08

with the equation of Snyder and Richards[5] is obtained if one assumes that only 62 percent of the collisions effective in broadening the absorption line also restore thermal equilibrium (see Table I, third column).

The results of Pond and Cannon[1] are more difficult to interpret, because in their experiment the energy density varied strongly along the guide as well as on a cross section, due to the standing waves set up in the equipment. Still, from the magnitude of the effect one can estimate the relaxation time to be of the order of ten microseconds. This means that collision with the wall is the mechanism that re-establishes thermal equilibrium. Most of the width of the line is therefore due to a non-dissipative cause, the Doppler effect. The theory so far developed cannot be applied to interpret the experiment. One may notice, however, that over the 200-fold variation in incident power investigated by Pond and Cannon, the absorption coefficient varies inversely as the cube root of the power. Hence, this is the transition region from constant absorption coefficient (low power level) to constant total power absorbed (high power level). It is somewhat surprising that the transition is so gradual.

To summarize, then: the data on the saturation of absorption lines broadened only by intermolecular collisions are in agreement with a theory which treats Zeeman components as independent contributors to the absorption and assumes that all collisions restore thermal equilibrium.

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On Infinite Field Reactions in Quantum Field Theory

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IN interpreting the level-shift of the hydrogen atom in terms of the radiative reaction, Bethe[1] proposed a method of dealing with this problem without touching the inherent divergency of the current quantum field theory. By his theory it has become possible to treat the problem involving field reactions for the first time in close connection with the reliable experimental data. On the other hand, Lewis[2] and Epstein[3] analyzed the infinities occurring in the radiative correction to the scattering cross-section of an electron in an external field of force and found that also these infinities could be got over by means of a procedure similar to Bethe's. In a recent issue of the PHYSICAL REVIEW, Schwinger[4] pointed out that in these problems the method of canonical transformation was useful, by which the separation from the fields of the parts belonging to free photons and non-radiating electrons was performed, a method which can be regarded as a relativistic generalization of the procedure used by Bloch and Nordsieck[5] as well as by Pauli and Fierz[6] in the discussions about the self-field of an electron.

Almost the same line of attack was taken independently of these American authors also by our Tokyo group and some results are now in course of publication in our English journal, *Progress of Theoretical Physics*. Under the unfavorable conditions after wartime, however, it will be a long time before these papers will appear in print. So I should like to give here a brief summary of the state and views of our investigations.

We first treated the effect of field reactions in the collision problem on the *f*-field theory of Pais[7]—or the *C*-meson theory of Sakata,[8] which had been developed by Sakata independently of Pais—intending to examine whether this theory which had been put forward aiming at the elimination of the infinity occurring in the self-energy of charged particles, was also capable of cancelling out the infinity occurring in the scattering cross section of an electron. We found that this was really the case: the *f*-field was proved capable of compensating one part of the infinite reactions of the radiation field in this phenomenon. The other part of infinities, that is, of the positron theoretical origin, however, could not be eliminated by introducing this new field.[9]

Then the above mentioned work of Bethe appeared. We tried[10] to formulate Bethe's procedure in a mathematically more closed form by using a relativistic generalization of the canonical transformation of Pauli and Fierz. By this transformation an infinite term could be separated in the Hamiltonian density, and this term, we found, had the same form as the mass term in the Dirac equation, being bilinear in ψ^* and ψ. Because of its structure this infinite term can be amalgamated into the mass term of the Dirac equation and one can reinterpret the electron mass in such a way that the compound mass is just what we observe, corresponding to the idea of Bethe. This procedure violates neither the invariance of the theory nor the integrability condition of the generalized Schrödinger equation.[11] In order to investigate the effectiveness of this amalgamation of infinity into the electron mass, we applied the method to the problem lying close at our hand, i.e., the radiative correction to the scattering cross section of an electron.[12] We found this amalgamation was in fact effective in eliminating the non-positron theoretical infinity in this problem, a fact that was pointed out independently by Lewis. It was also shown that the infinity of the positron theoretical origin could be eliminated by reinterpreting the scattering external potential or by reinterpreting the electron charge.

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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[10] T. Tati and S. Tomonaga, lecture at the symposium on the theory of elementary particles, Nov. 1947. Full account of this lecture will be published in Progress of Theoretical Physics.
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[13] Z. Koba and G. Takeda, appearing in Prog. Theor. Phys.
[14] M. Taketani, private conversation.
[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

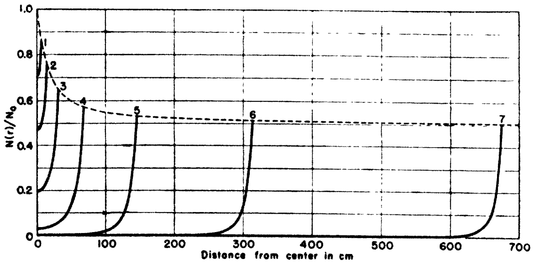

FIG. 1. The radial variation in the intensity of primary cosmic radiation (or in the relative helium content) in spherical iron meteorites of various masses. The numbers at the top of the curves are log mass in kg.