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.

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Erratum: Natural Radioactivity of Rhenium

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

S. N. Naldrett and W. F. Libby
Institute for Nuclear Studies, University of Chicago, Chicago, Illinois

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

F. J. Dyson
Cornell University, Ithaca, New York
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

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

it is easy to show that the vector interaction disappears entirely, except for a δ-function interaction between nucleons as before. Thus, the vector interaction leads to no physical processes in any order.

For vector and pseudovector meson fields, the corresponding gauge transformations lead only to the elimination of the longitudinal parts of the fields. As is well known, a nucleon may have two distinct couplings with the electromagnetic field, the first characterized by its charge and the second by its anomalous magnetic moment.[5] Thus a vector or pseudovector field has two distinct forms of interaction with a nucleon, as given by Kemmer, but a scalar or a pseudoscalar field has essentially only one.

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