however, that Hulme's criticism was removed in a rigorous treatment of the problem for the high energy limit in 1936.[5] Heitler in particular requotes the same criticism in the second edition of reference 2 in 1945. Current practice, on the other hand, appears to follow the pattern of quoting the criticism stated by Heitler, and then of using the formula anyway because it fits the data so well.

It is hoped that the present letter will suffice to establish recognition of the rigorous treatment on which Eq. (1) is based.

[1] E.g., W. Heitler, *The Quantum Theory of Radiation* (Clarendon Press, Oxford, 1945), second edition; Bishop, Collie, Halban, Hedgran, Siegbahn, du Toit, and Wilson, Phys. Rev. **70**, 113 (1950).
[2] See W. Heitler, reference 1, p. 126.
[3] H. Hall, Phys. Rev. **45**, 620 (1934).
[4] Hulme, McDougall, Buckingham, and Fowler, Proc. Roy. Soc. (London) **139**, 131 (1935).
[5] H. Hall, Revs. Modern Phys. **8**, 395 (1936).

New Aspects of the Pseudoscalar Meson Theory*

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We wish to demonstrate here a canonical transformation on the hamiltonian describing the interaction of a neutral pseudoscalar meson field with a single nucleon through pseudoscalar coupling, which has the property that it reveals the equivalence theorem between pseudoscalar and pseudovector coupling in a new light and at the same time reduces the hamiltonian to a form in which it may be amenable to strong-coupling treatment.

The hamiltonian with which we begin is

$$H=\beta M+\boldsymbol{\alpha}\cdot\mathbf{p}+ig\beta\gamma^5\varphi_0+H_\mu,\quad H_\mu=\tfrac{1}{2}\int\{\pi^2+(\nabla\varphi)^2+\mu^2\varphi^2\}d\mathbf{x}, \quad (1)$$

where all symbols have their usual meaning, units are chosen so that $\hbar$ and c are unity, and the subscript 0 represents the evaluation of the corresponding meson field quantity at the nucleon position. Under the canonical transformation

$$H\rightarrow H'=e^{iS}He^{-iS}$$

with

$$S=\tfrac{1}{2}\gamma^5\tan^{-1}\{g\varphi_0/M\} \quad (2)$$

the hamiltonian takes the form

$$H'=\beta M[1+g^2\varphi_0^2/M]^{\frac{1}{2}}+\boldsymbol{\alpha}\cdot\mathbf{p}+H_\mu +\frac{g}{4M}\left\{\frac{1}{1+g^2\varphi_0^2/M^2}[\boldsymbol{\sigma}\cdot\nabla\varphi_0-\gamma^5\pi_0] +[\boldsymbol{\sigma}\cdot\nabla\varphi_0-\gamma^5\pi_0]\frac{1}{1+g^2\varphi_0^2/M^2}\right\} +\frac{g^2}{8M^2}\int\left[\frac{\delta(\mathbf{x}-\mathbf{x}_0)}{1+g^2\varphi_0^2/M^2}\right]^2 d\mathbf{x}. \quad (3)$$

Hence we see that pseudoscalar coupling is equivalent to a nonlinear pseudovector coupling together with some additional non-spin-dependent nonlinear coupling terms.[1] It should be noted that the above transformation is exact to all orders in the coupling constant in contradistinction to other derived forms of the equivalence theorem.[2] The strong nonlinearity of the hamiltonian in the meson field is reminiscent of recent heuristic proposals by Heisenberg,[3] Finkelstein and Ruderman,[4] and Schiff,[5] and suggests the possibility that pseudoscalar meson coupling may provide the elements required for the explanation of nuclear force saturation and of the relative independence of one-particle motions in nuclei required by the nuclear shell model on a basis other than exchange forces.

The hamiltonian (3) is in a form such that the method of Foldy and Wouthuysen[6] may be applied to obtain the equivalent nonrelativistic hamiltonian. The result, disregarding all terms which vanish as the nucleon becomes infinitely heavy (after writing $g=fM$ and assuming f remains finite as $M\rightarrow\infty$), is

$$\mathcal{H}=M[1+f^2\varphi_0^2]^{\frac{1}{2}}-[\tfrac{1}{2}f\boldsymbol{\sigma}\cdot\nabla\varphi_0/(1+f^2\varphi_0^2)] +H_\mu+\frac{f^2}{8}\int\left[\frac{\delta(\mathbf{x}-\mathbf{x}_0)}{1+f^2\varphi_0^2}\right]^2 d\mathbf{x}. \quad (4)$$

By the introduction of suitable source functions, it would appear possible to treat the hamiltonian (4) by the methods previously developed for strong coupling.

Similar treatments are possible for the charged pseudoscalar meson field with pseudoscalar coupling and for the second-quantized form of the Dirac field in both the Schrödinger and interaction representations. These, together with further investigations of the strong-coupling theory, will be presented in future publications.

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[1] The last term is of course strongly divergent. However, in the second-quantized form of the Dirac theory its analog is the more familiar "contact" term.
[2] See, for example, K. M. Case, Phys. Rev. **76**, 1 (1949).
[3] W. Heisenberg, Z. Naturforsch. **5a**, 151 (1950).
[4] R. Finkelstein and M. Ruderman, Phys. Rev. **81**, 655 (1951).
[5] L. I. Schiff, Phys. Rev. **80**, 137 (1950); Phys. Rev. **83**, 239 (1951).
[6] L. L. Foldy and S. A. Wouthuysen, Phys. Rev. **78**, 29 (1950).

Nuclear Spin of Actinium 227

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As part of a joint investigation of the actinium spectrum, interferometer exposures were made which yielded about 15 lines showing well-resolved hyperfine structure. The structure was in the form of flag patterns with either three or four components, with large degradation of spacing and intensity indicating a low nuclear spin. Since no more than four components were observed in spite of J values of at least 3 as shown by a term analysis, the number of levels in the split term is spin-limited, with $I=\frac{3}{2}$ for Ac^{227}, the isotope used. Evaluation of the nuclear magnetic dipole and electric quadrupole moments must await a more complete analysis of the spectrum, and will be reported later.

Erratum: A Self-Consistent Treatment of the Oxygen Dissociation Region in the Upper Atmosphere

[Phys. Rev. **83**, 109 (1951)]

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In Eq. (25) replace G_2 by G_2'.

In Appendix 1, replace the last two lines by "where G_1' is the statistical weight of two atoms in the ^3P state, and G_2' is 1 and is hence different from G_2."

In Appendix 4, Eq. (50) should be replaced by

$$B=\int_0^\infty \beta_v vF(v)dv=4.20\times10^{-21}T^{\frac{1}{2}}. \quad (50)$$

The value of B for $T=300°K$ is 7.25×10^{-20}. The equation for B' should be replaced by

$$B'=\int_0^\infty \beta_v' vF(v)dv=(G_1/G_1')(G_2'/G_2)(\nu_1^0/\nu_0)^2B\cong(1/24)B.$$

The above corrections do not affect any of the other results in the paper, since the correct expressions were used in calculating the results.

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