The experiments were put aside at that time owing to the press of other work and approximately a year later they were again investigated with the help of a scintillation counter. In the present work two sets of experiments were performed.

In the first set of experiments, in order to get a good calibration point for this low energy radiation, the low energy radiations from Tl^{204} were compared with those of Os^{185}, a known K-capturer.[2,3] By using the line produced by Os^{185} (K_α of Re) as a calibration point, the radiation from Tl^{204} had an energy of 68 kev.

In a second set of experiments, the photon radiations from Tl^{204} were compared directly with those from Tl^{200}, which is known to decay to Hg^{200} by electron capture.[4] The results of these experiments, taken with a scintillation counter are shown in Fig. 1. It will be seen that the peak of the curve, owing to the K_α x-rays of Hg from Tl^{200}, falls at exactly the same place as that of the photons from Tl^{204}.

From the above experiments, it is to be concluded that the photons from Tl^{204} are the K_α x-rays of Hg and that Tl^{204} decays to Hg^{204} by K-electron capture. While these experiments were in progress, a similar conclusion was obtained by Lidofsky, Macklin, and Wu.[5]

† Supported by the joint program of the ONR and AEC.
1 Mitchell, Canada, and Cuffey (unpublished).
2 Bunker, Canada, and Mitchell, Phys. Rev. **79**, 610 (1950).
3 M. M. Miller and R. G. Wilkinson, Phys. Rev. **83**, 1050 (1951).
4 H. I. Israel and R. G. Wilkinson, Phys. Rev. **83**, 1051 (1951).
5 Lidofsky, Macklin, and Wu, Phys. Rev. **87**, 204 (1952).

A Proposed Re-Interpretation of Quantum Mechanics

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In two recently published extensive papers,[1] Bohm has given a full discussion of an alternative interpretation of nonrelativistic quantum mechanics proposed by him. It is Bohm's opinion that there exists the possibility of looking on nonrelativistic quantum mechanics as a form of classical mechanics involving special quantum forces. While the bulk of the papers is devoted to various applications of this view, the fundamental point is contained in a few remarks concerning the solution of Schrödinger's equation, at the beginning of Bohm's first note.

Writing, as customarily,

$$\psi = R(x, y, z, t)\exp(iS/\hbar) \quad (R, S \text{ real}), \tag{1}$$

the Schrödinger equation is split into two equations:

$$(\partial R/\partial t)+(1/2m)(R\Delta S+2\,\text{grad}R\cdot\text{grad}S), \tag{2a}$$

$$(\partial S/\partial t)+(1/2m)(\text{grad}S)^2+V(x, y, z, t)-\frac{\hbar^2}{2m}\frac{(\text{grad}R)^2}{R}. \tag{2b}$$

Equation (2b) is looked upon as the Hamilton-Jacobi equation of the quantum-mechanical problem, in which the terms containing R and its derivatives are a sort of quantum potential energy. Since it is necessary to satisfy also (2a), Bohm simply suggests the use of an arbitrary solution ψ of the Schrödinger equation. One is then certain that both (2a) and (2b) will be satisfied.

We do not want to enter here into a discussion of the individual cases treated by Bohm. It is the thesis of the present letter that so far no possibility of a mechanical interpretation has been demonstrated.

To obtain the solution of a mechanical problem, it is necessary to have a solution S which depends on the coordinates of the system, the physical parameters entering into the expression for kinetic and potential energy and f nonadditive integration constants. Bohm has failed to show that such a function can be found.[2]

It is, of course, true that, thanks to the infinite number of eigenstates, as many constants as one wishes can be introduced into S; but these are not integration constants in the sense of the Hamilton-Jacobi theory, since they will in general also be present in the "quantum potential" described by R and its derivatives. There does not seem to exist a general formulation by which (2a) and (2b) can be satisfied and S still be made to contain f (nonadditive) integration constants that are not present in R. Until a way to find these integration constants has been devised, the similarity with the Hamilton-Jacobi theory is purely extraneous, and one cannot talk about a mechanical interpretation of the wave equation.

It may perhaps be kept in mind that the whole procedure suggested by Bohm is, even in its present incomplete form, strictly limited to nonrelativistic quantum mechanics and there is no indication given as to how it could possibly be extended to include relativistic (spin) phenomena; nor has an attempt been made in any of the examples to analyze the fundamental relativistic questions of observables and their measurability.[3]

Keeping in mind these factors together with the difficulties in the purely mechanical part of the interpretation, one may feel justified in concluding that no alternative interpretation of quantum mechanics has been offered.

1 D. Bohm, Phys. Rev. **85**, 166; **85**, 180 (1952).
2 To put the momentum vector equal to the gradient of S (as defined by Bohm) disposes of f integration constants in a nonmechanical manner which may be compared to the quantization of the phase-integrals in the old quantum theory.
3 O. Halpern and M. H. Johnson, Phys. Rev. **59**, 896 (1941).

Reply to a Criticism of a Causal Re-Interpretation of the Quantum Theory

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In a letter[1] criticizing a causal re-interpretation of the quantum theory proposed by the author,[2] Halpern comes to the conclusion that "no alternative interpretation of the quantum theory has been offered." In the present letter, the author wishes to discuss in some detail the arguments by which Halpern is led to this conclusion.

Halpern's first objection is that because the function, $S(\mathbf{x})$, appearing in paper I, Eq. (6), does not depend on f nonadditive integration constants, one has not yet obtained a solution of the mechanical problem. It was stated in paper I, Sec. 4, however, that the Hamilton-Jacobi theory was being used only for the purpose of indicating in a simple way how one might arrive at a causal interpretation of the quantum theory; while the theory itself was to be based directly on the equations of motion [paper I, Eq. (8a)]:

$$md^2\mathbf{x}/dt^2=-\nabla\{U(\mathbf{x})+V(\mathbf{x})\},$$

where $V(\mathbf{x})$ is the classical potential, and $U(\mathbf{x})$ is the "quantum-potential." Now, the solution of these equations by the Hamilton-Jacobi technique would certainly require the f nonadditive integration constants referred to by Halpern, but the author intended to employ another method of solution in his papers; namely, that of guessing a function and verifying it by direct substitution in the differential equations. Since the treatment given in the papers is perhaps not completely explicit, it may be useful to amplify it here. Guided by the Hamilton-Jacobi theory, we guess tentatively that if the momentum were equal to $\mathbf{p}=\nabla S(\mathbf{x})$, this function would satisfy the equations of motion. Now,

$$d\mathbf{p}/dt=\partial\mathbf{p}/\partial t+(\mathbf{v}\cdot\nabla)\mathbf{p}=\partial(\nabla S)/\partial t+\nabla(\nabla S)^2/2m.$$

But since S is defined as the phase of the wave function, we have (paper I, Eq. (6))

$$\partial S/\partial t=-(\nabla S)^2/2m-V-U, \quad d\mathbf{p}/dt=-\nabla\{V+U\}.$$