one, the effective range is much smaller than that observed (1.56×10^{-13} cm). A short range repulsion, however, much increases the effective range, and for B equal to one, the effective range is nearly large enough. It is apparent that a choice of B only slightly larger than one, or a slight increase in the radius of repulsion, would increase the effective range sufficiently to give agreement with experiment.

We conclude that the singular potential of Eq. (2) can give the effective range correctly, but only if (1) the potential has a long tail, i.e., B equal to one, or greater; (2) there is a strong repulsion at distances less than the nucleon Compton wavelength.

Conditions (1) and (2) might well follow from a careful treatment of pseudoscalar meson theory or as a consequence of the strong coupling of heavy "mesons"; hence we are unable to point to a clear-cut contradiction with experiment.

[1] Harvard lecture notes (hectographed), quoted by J. Blatt, Phys. Rev. **74**, 92 (1948).
[2] H. A. Bethe, Phys. Rev. **76**, 38 (1949).
[3] Rochester and Butler, Nature **160**, 855 (1947).
[4] A. J. Seriff *et al.*, Phys. Rev. **79**, 204A (1950).
[5] It is apparent that a modification of the nonrelativistic potential inside the nucleon Compton wavelength, $\hbar/Mc$, is equivalent to a modification of the boundary condition on the wave function at $r=\hbar/Mc$, which can be the result of unknown effects occurring inside this range.

A Difficulty in Fröhlich's Theory of Superconductivity

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FRÖHLICH[1,2] has recently proposed a theory of superconductivity which is based on the interaction of the lattice vibrations with the conduction electrons. As a starting point, he investigates the ground state of the system, electrons plus lattice oscillators, treating their interaction by perturbation theory. He finds that when the strength of the interaction exceeds a certain critical value, the usual second-order perturbation expression,

$$E_s'=E_s+\Sigma_n|H_{sn}|^2/(E_s-E_n), \qquad (1)$$

gives a slightly lower (finite) energy if one starts not from the ground state in the absence of interaction (electrons filling the Fermi-sphere, oscillators unexcited), but rather from a state in which an appropriate shell of electrons has been displaced from the Fermi sphere, while the oscillators remain in their ground state. Fröhlich himself has remarked that the application of perturbation theory to such an excited state is somewhat doubtful, since in that case E_s is degenerate with many E_n and thus the sum in Eq. (1) contains singularities. Nevertheless, he obtained finite results by taking principal values in his integrations, and he concluded that the ground state of the system is described by a shell distribution.

Since the existence of the shell state is basic in this theory, we have examined more closely whether the use of Eq. (1) is justified in this case. In this connection we have considered another type of initial state, namely, one in which the electrons fill the Fermi sphere (for simplicity), but the oscillators are in excited states. It was thought that for strong enough interactions the resulting negative perturbation energy might more than offset the increase in zero-order energy due to the excitation of the oscillators. The total energy was calculated by the doubtful Eq. (1), using a procedure quite analogous to that of reference 1. One notes first that the oscillator with wave vector $\mathbf{w}$ contributes a term $(n_w+\frac{1}{2})\hbar\omega_w$ to the zero-order energy, where n_w is its level of excitation and ω_w its frequency. Furthermore, the squares of the matrix element involving the oscillator $\mathbf{w}$ are proportional to n_w+1 for emission, and to n_w for absorption of a phonon. Hence, this oscillator contributes a term of the form $-F(A_w+B_wn_w)$ to the perturbation energy, where F is a measure of the strength of interaction (see reference 1). It will now be seen that if for any $\mathbf{w}$, $FB_w>\hbar\omega_w$, it becomes energetically favorable for the corresponding oscillator to be infinitely excited. A simple calculation shows that this condition can be written as $2\alpha_wF\nu>1$, where ν is the number of conduction electrons per atom and

$$\alpha_w=\tfrac{1}{2}+\tfrac{1}{4}[(2k_0/w)-(w/2k_0)]\log|(2k_0+w)/(2k_0-w)| \qquad (2)$$

(k_0=electronic wave number at Fermi surface). The maximum value of α_w is 1 (at $w=0$), so that as soon as

$$2F\nu>1, \qquad (3)$$

it follows that the energy can be lowered indefinitely by highly exciting the appropriate oscillators, a result which is quite unphysical.

It is now difficult to see how the existence of the shell state can be established from Eq. (1). For suppose that the latter is tentatively accepted. Then, whenever according to Fröhlich the interaction is strong enough to lead to the shell state and thus to superconductivity,[3] the condition (3) is satisfied. Hence, states with even lower energy would exist. On the other hand, the fact that the energy of these states can be made arbitrarily low is an indication that it is unsafe to draw any conclusions from Eq. (1) once the inequality (3) is satisfied.

When this calculation was completed, we received through the kind offices of Professor C. Møller a manuscript by Professor G. Wentzel in which similar conclusions were reached from a somewhat different point of view.

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[1] H. Fröhlich, Phys. Rev. **79**, 845 (1950).
[2] H. Fröhlich, Proc. Phys. Soc. (London) **64**, 129 (1951). See also J. Bardeen, Phys. Rev. **80**, 567 (1950); Phys. Rev. **81**, 829 (1951).
[3] According to Eq. (3.19), reference 1, and Errata, reference 2, the condition that the shell state is the ground state is $2\nu F>1$ if $4\nu<1$; in the case $4\nu>1$, it is $(\nu/2)^{\frac{1}{2}}F>1$ so that *a fortiori* $2\nu F>1$.

On the *K*-Capture/Positron Branching Ratio for Cu^{61}

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SIGNIFICANT in all the experimentally determined values which have been reported[1] to date for the K-capture/positron ratio for the decay of Cu^{61} have been a number of instrumental correction factors. These have been brought about by the effects of the measuring instrument upon the emitted radiations, primarily the low energy x-rays and Auger electrons. It is perhaps of interest to note that this ratio can be obtained through a combination of the results of two measurements which have not required the use of instrumental correction factors. In the first place Reynolds[2] has used an ingenious method, utilizing mass spectroscopic relative isotopic abundance measurements, to determine the K-capture/positron ratio for Cu^{64}. This yields a value $(K/\beta^+)_{64}=2.32$.

The ratio $(K/\beta^+)_{64}/(K/\beta^+)_{61}$ also has been measured[3] without any required instrumental correction factors. This stems from the fact that the x-rays associated with K-capture occur at the same energy for both these isotopes. As a result any correction needed for one will be needed in the same amount for the other, and a ratio determination eliminates the need for their use. The value for this ratio has been determined as 5.5. Combining these figures,