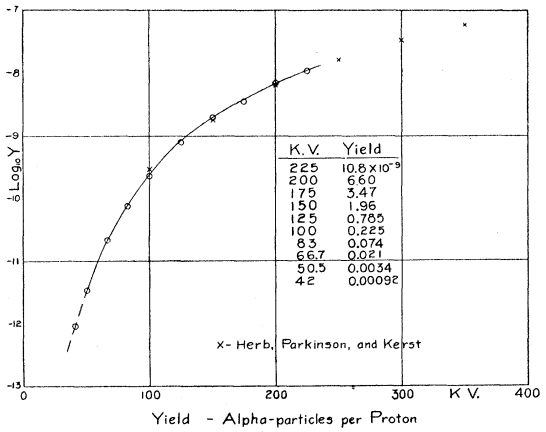

FIG. 1.

range of voltage, but tends to increase less rapidly at the higher voltages.

It is of interest for the theory of the nucleus to know the yield also at lower voltages than those covered so far because more accurate information can then be obtained about the potential inside the nucleus.[6] Since the data of Herb, Parkinson and Kerst are less accurate at the lower voltages it was thought worth while to extend observations to still lower voltages as well as to repeat them in a region overlapping theirs in order to obtain an independent determination with a different experimental arrangement.

Observations have been made of the thick film yield for proton energies ranging from 40 to 225 kv. Ions, including protons, were obtained from a low voltage hydrogen arc of the type described by Tuve, Dahl and Van Atta.[7] The high voltage was generated by a doubling rectifier circuit of the type used by Cockcroft and Walton. The ions were drawn from the arc by a small probe, focused by a metal cylinder, and then accelerated down a tube consisting of four glass sections separated by metal plates. The potential adjustment of the focusing cylinder and the potential distribution down the accelerating tube were maintained by corona leaks. The protons were separated from the other ions in the beam by passing them through a magnetic field, which after careful plotting and numerical integration served also to measure their equivalent voltage.

The protons were allowed to fall onto a lithium target, obtained by evaporation in vacuum onto a small sheet of nickel, and placed at an angle of 45° to the beam. The alpha-particles were let pass through a mica window into an ionization chamber, and then counted by means of a linear amplifier, of the type used by Dunning, together with a scale-of-four thyratron circuit coupled to a mechanical counter. The average proton current was measured by taking continuous readings on a galvanometer.

The absolute yields were calculated on the assumption of uniform angular distribution of the alpha-particles, and are expressed as the total number of alpha-particles per impinging proton. The results are shown in the accompanying figure together with the data of Herb, Parkinson and Kerst, both plotted on a logarithmic scale. Except for the lowest two points the yield values correspond to observations of from 5000 to 20,000 counts. At the lowest point about 90 counts were observed; and at the next point, about 900—so that these two points are subject to correspondingly greater statistical errors. It is seen from Fig. 1 that, within the limits of experimental error, these data are in good agreement with those of Herb, Parkinson and Kerst (except for their lowest point at 100 kv, for which they do not claim as high accuracy as for the other points). The theoretical significance of these data is discussed in an article by Ostrofsky, Briet and Johnson.[6]

The authors wish to express their thanks to Professor G. Breit, at whose instigation this problem was undertaken, for his generous interest and advice throughout the progress of the work. It is also desired to acknowledge indebtedness for grants-in-aid made to G. Breit by the Carnegie Institution of Washington and to C. E. Mendenhall and G. Breit by the American Philosophical Society, which made it possible to carry on this work.

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October 26, 1935.

[1] J. D. Cockcroft and E. T. S. Walton, Proc. Roy. Soc. **A137**, 229 (1932).
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[5] L. R. Hafstad and M. A. Tuve, Phys. Rev. **48**, 314 (1935).
[6] See M. Ostrofsky, G. Breit and D. P. Johnson, this issue.
[7] M. A. Tuve, O. Dahl and C. M. Van Atta, Phys. Rev. **46**, 1027 (1934).
We are indebted to Dr. Tuve for providing us with detailed specifications for the construction of this arc.

Ionic Dispersion in the Extreme Infrared

In many respects the following problem resembles that of the application of Maxwell's equations to the reflection and absorption of infrared radiation by thin metallic films, except that in the case of electrolytes the mass of an ion is sufficiently greater than the mass of an electron to introduce an inertia term.

Assuming the motion of an ion to satisfy the equation

$$Mdv/dt+\rho v=e\mathcal{E}e^{i\omega t}, \tag{1}$$

where M is the mass of an ion, ρv the frictional force and $e\mathcal{E}e^{i\omega t}$ force from the alternating electric field, a characteristic value is obtained when $\rho=\omega M$. If Stokes' law of friction is applied, the characteristic wave-length, λ_0 (in μ) for which the inertia of an ion becomes important is given by:

$$\lambda_0=1.65M/\eta r, \tag{2}$$

where r is the radius of an ion (in A) and η is the specific viscosity of the solution. For electrolytes of KCl and KI, $\lambda_K=48\mu$, $\lambda_{Cl}=32\mu$ and $\lambda_I=95\mu$.

In Fig. 1 are shown the absorption coefficients and the reflecting powers of water, 3 normal KCl and 4 normal KI solutions. These data are chosen as illustrative of ionic dispersion and are taken from investigations on different concentrations of HCl, LiCl, NaCl, KCl, KBr, LiI, KI, ZnI_2, H_2SO_4, $MgSO_4$ and KOH.

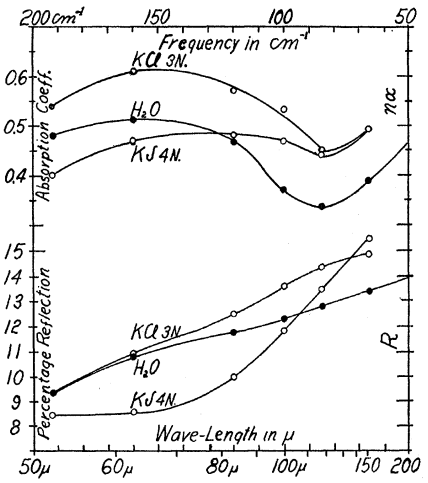

FIG. 1.

The characteristic wave-lengths for K, Cl, and I ions given above were calculated under the assumption that the ions were free to move with respect to the water molecules surrounding them. A comparison of the curves for KCl with those for KI seems to justify this assumption, at least for the amplitudes produced by the radiation employed. The rigid attachment of water molecules to the ions might be expected to change the ratio of M to r in Eq. (2) so that the characteristic wave-lengths would not be consistent with the data shown in the figure. A better criterion for deciding if there are water molecules attached to the ions is offered by considering the value of the absolute absorption as obtained from inserting the above equations in Maxwell's equations. A calculation shows that the ions in KCl and KI solutions are free to move with respect to the surrounding water molecules. However, in electrolytes of LiCl and $MgSO_4$ our data indicate that water molecules move with the ions. It seems noteworthy that the viscosities of KCl and KI solutions are practically the same as that of pure water while LiCl and $MgSO_4$ solutions are considerably more viscous. Also electrolytes of Li and Mg ions have abnormally small electrical conductivities.

We conclude that the dispersion of electrolytes in the extreme infrared can be pictured classically by considering the ions to follow in translation the alternations of electromagnetic waves. The motion of the ions decreases in amplitude as the frequency of the radiation increases because of their inertia and the friction against the neighboring molecules. In electrolytes of KCl and KI, the ions seem to move with respect to the water molecules except for friction.

I am indebted to Professor P. Debye, for having kindly derived the appropriate equations, and to Professor J. Errera, the University of Brussels, the Fonds National Belge de la Recherche Scientifique, and C. R. B. Educational Foundation for their generous help.

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November 30, 1935.

Exchange Forces and the Structure of the Nucleus

The forces between elementary particles in the nucleus have been supposed to be of three types, which may be denoted as Wigner, Heisenberg or Majorana. The Wigner forces are of the ordinary kind, not involving exchange; the Heisenberg forces involve an exchange of both spin and space coordinates; and the Majorana forces involve an exchange of space coordinates alone.

According to Wigner,[1] one might account for the large neutron-proton scattering cross section by assuming the interaction of neutron and proton to depend on the relative orientation of the spins. Van Vleck[2] has suggested that, since the Heisenberg forces depend on spin orientation and the Majorana forces do not, the interaction could be described by a linear combination of Heisenberg and Majorana forces. Feenberg and Knipp[3] have shown that such an interaction can give an arbitrarily large scattering cross section, provided that the proper linear combination is chosen. It does not seem to the present writer, however, that the treatment is complete, since there is still another type of exchange conceivable, and this is obtained by making a Heisenberg exchange and then a Majorana exchange. This amounts to interchanging the spin coordinates and not the space coordinates. (We could perhaps compare the present situation to the interaction of an excited atom with a normal atom. Two types of processes occur here, and have been denoted by "austausch" and "resonance," respectively. The effect due to combination of the two is of the same order of magnitude as that of each alone.) The most general exchange operator would then include this spin exchange term as well as the others.

In this connection, a rather convenient formalism for treating the nucleus as a many-body problem suggests itself. Following Heisenberg,[4] one can suppose all the particles in the nucleus to be identical, but just in different states. The interaction operator will then be, in this scheme, the same for all pairs of particles. If now, we take the resulting wave function for the total system to be a determinant wave function, an analysis similar to that of Slater[5] can be carried through. If $V(12)$ is the above interaction operator, and if m and n denote space-spin states, while ν, π denote proton, neutron, respectively, then we obtain integrals of the type $\int u^*(m\nu/1)u^*(n\pi/2)V(12)u(m\nu/2)u(n\pi/1)d\tau_1 d\tau_2$. Here, particle 1 makes a transition from state m, ν to state n, π, while particle 2 does the opposite. That is, this integral represents a matrix element of the interaction between neutron and proton. It may be possible, from the observed masses of the light elements, to determine these matrix elements. A study of this is now being made, and will be reported later.

I wish to thank Dr. Feenberg for allowing me to see his manuscript before publication.

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University of Illinois,
December 14, 1935.

[1] Feenberg and Knipp, Phys. Rev. **48**, 906 (1935); footnote 13.
[2] Feenberg and Knipp, Phys. Rev. **48**, 906 (1935).
[3] Reference 1, footnote 14.
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