LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the twentieth of the preceding month; for the second issue, the fifth of the month. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Evidence for the Existence of an Isotope of Potassium of Mass 40

Recently Klemperer[1] and Newman and Walke[2] have suggested that the facts about the radioactivity of potassium could best be correlated by assuming the existence of a rare radioactive isotope of potassium of mass 40. There was no direct evidence for this isotope and Bainbridge[3] had estimated that if such an isotope existed the ratio of its abundance to that of K^{39} must be less than 1/300. It occurred to me that with the mass spectrograph at my disposal it would be possible either to detect such an isotope or to set a much lower limit on its abundance ratio.

The mass spectrograph used by Tate and Smith[4] has been rebuilt to give greater resolving power. One of the vacuum tube amplifiers described by Distad and Williams[5] was used to measure the analyzed positive ion current.

The potassium was prepared by heating KCl with metallic Ca. It was repeatedly distilled before being introduced into the spectrograph.

Fig. 1 shows the interesting portion of one of many mass spectrographic analyses of the region around $m/e=40$. As may be seen there is a very definite peak due to an ion with an m/e value of 40. The rising portions on either side of this peak are the feet of the very much larger peaks due to K^{39} and K^{41}. The sensitivity and resolving power of the spectrograph is indicated by the fact that if these latter peaks were plotted on the same scale as Fig. 1 they would have heights of 44,300 and 3190 units, respectively.

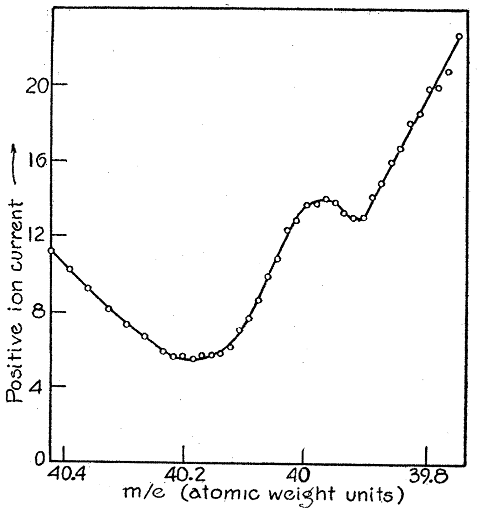

FIG. 1. Typical mass spectrographic analysis of region around mass 40. Potassium vapor in tube, 8.4 volts applied to electrons. Height of peak at 39, 44,300; at 41, 3190 units.

The average value of the ratio of the height of the peak due to the ion at 40 to that of the peak due to K^{39} is 1/8600 with a probable error of approximately 10 percent. The ratio of the heights of the peaks due to K^{39} and K^{41} is 13.96 ± 0.1 which agrees well with the abundance ratio of $K^{39}/K^{41}=13.88\pm0.4$ given by Brewer and Kueck.[6]

There remains the problem of identifying the ion at $m/e=40$. The following considerations lead definitely to the conclusion that it is a rare isotope of potassium, K^{40}.

1. By varying the potential applied to the electrons producing the ion in question its ionization potential was directly compared to that of K^{41}. Fig. 2 shows the results. The ionization potential of the ion at 40 is the same as that of potassium (4.32 volts) with an uncertainty which appears to be less than 0.5 volt. Consequently the ion at 40 cannot be due to any element or compound the ionization potential of which is greater than 5 volts. In particular it cannot be Ca^{40} or A^{40}. The possibility that it might be Ca^{40} was given particular consideration because of the method of preparing the potassium and because Ca might come from the heated glass walls, although calculation showed that the vapor pressure of Ca would be too low at the temperatures used to account for the magnitude of the peak observed.
2. The ratio of the heights of the peaks at 39, 40 and 41 remained constant, within experimental error, over a sixfold variation of the pressure of potassium vapor.
3. At electron energies of about 100 volts, peaks were found at m/e values of $19\frac{1}{2}$, 20 and $20\frac{1}{2}$ corresponding to K^{++}. The ratios of their heights were the same, within experimental error, as for the singly charged ions.

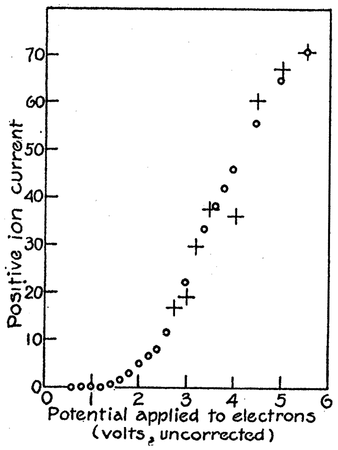

FIG. 2. Comparison of ionization efficiency curves for K^{41} (circles) and ion of mass 40 (crosses). The points at potential 5.5 volts are made to coincide.

4. Na was present as an impurity. Because of the slight chance that the ion at 40 might be $(NaOH)^+$ a search was made at 56 and 58 for $(KOH)^+$. No trace was found.

5. If the peak at 40 were due to $K^{39}H$ a corresponding one at 42 due to $K^{41}H$ should have been present in abundance 1/14 as great. None was present in abundance greater than 1/150,000 of K^{39}. Neither $(H_2O)^+$ nor H_2^+ could be detected in the tube.

6. At the higher pressures peaks were found at masses 78 and 80 corresponding to $(K^{39}K^{39})^+$ and $(K^{39}K^{41})^+$. The peak at 40 could not, however, be due to $(K^{39}K^{41})^{++}$ because at the lower pressures the peak at 80 disappeared completely, as it should, while that at 40 remained.

It is estimated that the apparatus had sufficient sensitivity and resolving power to detect a peak at 40 of magnitude 1/45,000 compared to K^{39}. In the region of masses 42 and 43 there is less background than at 40. One can safely say that K^{42} and K^{43}, if present, were each present in abundance less than 1/150,000 relative to K^{39}.

I wish to express my appreciation to Professor John T. Tate for his valuable suggestions and interest in this work.

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July 15, 1935.

[1] Klemperer, Proc. Roy. Soc. **A148**, 638 (1935).
[2] Newman and Walke, Phil. Mag. **19**, 767 (1935).
[3] Bainbridge, J. Frank. Inst. **212**, 338 (1931).
[4] Tate and Smith, Phys. Rev. **46**, 773 (1934).
[5] Distad and Williams, Rev. Sci. Inst. **5**, 289 (1934).
[6] Brewer and Kueck, Phys. Rev. **46**, 894 (1934).

Remarks on the Theory of Protons and Neutrons

In a recent paper[1] the author attempted to write the equations of the proton and the neutron (considered as two quantum states of one heavy particle) in close analogy with Dirac's equations for the electron and Pauli's equations for the neutron.[2] Eight values of the spin-variable were used and two additional terms in the Hamilton-operator were introduced. These latter represented (1) the interaction of the tensor of the electromagnetic field with the electric and magnetic moment of the particle and (2) the interaction of the heavy particle with the quantized field of electrons and neutrinos. (This second interaction is analogous to that introduced by Fermi[3] in his theory of β-rays.)

We write:

$$(p_0-H/c)\psi=0,$$

where

$$H=H_{PN}+H' \tag{1}$$

and H_{PN} is the Hamilton-operator of the heavy particle:

$$\frac{1}{c}H_{PN}=\frac{e}{c}A_0\gamma-\alpha_4 Mc-\Sigma\alpha_k\left(p_k-\frac{e}{c}A_k\gamma\right)-\frac{e\hbar}{Mc}\Sigma\epsilon_{kl}\frac{\partial Ae}{\partial x_k}\cdot \tag{2}$$

Here ϵ_{kl} represents the components of the antisymmetrical tensor of the magnetic and electric moment of the heavy particle: $\epsilon_{23}=i\alpha_2\alpha_3\alpha_4\cdots$, $\epsilon_{01}=i\alpha_1\alpha_4\cdots$. γ is a matrix introduced in our previous paper in such a manner that the potentials A_k do not appear in the equations for a neutron. H' represents the interaction between the heavy particle and the electrons and neutrinos. It must be written so that the conservation laws of the energy and of the spin are respected; that is, every transition of a neutron into a proton must be accompanied by the emission of an electron and a neutrino (as by Fermi[3]). In the present paper we remark that the values of the magnetic moment of the proton $(3e\hbar/2Mc)$ and of the neutron $(2e\hbar/2Mc)$, which we obtain from (2) by introducing only one numerical factor $e\hbar/Mc$ (as a coefficient of ϵ_{kl}), are both in a satisfactory agreement with the values recently deduced by G. Kruger (2.7 and 1.75 nuclear magnetons) and with the measurements of the magnetic moment of the proton.

It seems also noteworthy that the interaction of the heavy particles with the electrons (represented, for instance, by the Dirac "density matrix") and neutrinos makes it possible to understand the oriign of the exchange forces between the proton and the neutron (considered by Heisenberg and E. Majorona).

A more detailed account of this question will be published shortly.

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Department of Physics,
July 22, 1935.

[1] Lincei R. (in press).
[2] J. F. Carlson and J. R. Oppenheimer, Phys. Rev. **41**, 63 (1932).
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The Relation Between Internuclear Distances and the Force Constants of Diatomic Molecules

Some time ago the writer called attention to the close relation, in diatomic molecules, between the internuclear distance, r_e, and the "bond force constant," k_e (defined as d^2V/dr^2 at the equilibrium separation) and proposed an equation expressing this relation,[1] which may be written as follows:

$$r_e=(C/k_e)^{\frac{1}{3}}+d_{ij}. \qquad \text{Relation I.}$$

This equation gives satisfactory agreement with experimental data if C is taken as a universal constant and d_{ij} is constant for all molecules made up of two atoms found in the ith and jth *rows* of the periodic table, respectively.

The writer has recently observed another relationship which may be expressed in an equation of just the same form:

$$r_e=(C_{mn}/k_e)^{\frac{1}{3}}+d_{mn}. \qquad \text{Relation II.}$$

In this case d_{mn} and C_{mn} are constant for the analogous electronic states of all molecules made up of two atoms found in the mth and nth *groups* of the periodic system, respectively. In other words a given pair of constants will fit the ground states, for example, of all molecules in such a set as Cl_2, Br_2, IBr, ICl and I_2; or CO, SiO, CS, TiO and PbO. Relation II gives even more satisfactory agreement