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 eighteenth of the preceding month, for the second issue, the third of the month. Because of the late closing dates for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Communications should not in general exceed 600 words in length.

Note on the Fine Structure of Hα and Dα

Various investigators[1] have found that the doublet separations of the Hα and Dα lines are somewhat smaller than the theoretically predicted values. Kemble and Present[2] pointed out that the discrepancy could be accounted for by a deviation from the Coulomb law at small distances from the nucleus, which leads to a displacement of the ^2S levels. However they found that the discrepancy was much too large to be explained on the basis of a finite size of the electron and proton.

Recently R. C. Williams[3] resolved a third component of the Dα line, and obtained the separations 0.319 cm^{-1} between components (1) and (2), and 0.135 cm^{-1} between components (3) and (2). These values are, respectively, 0.009 cm^{-1} less, and 0.027 cm^{-1} greater, than the theoretical values. Unpublished results obtained by Houston and Robinson by means of a Fourier analysis of the Dα line give a similar discrepancy, although the deviations found are not quite as large as those obtained by Williams.

It seems significant that both of these deviations are consistent with a perturbation of the 2^2S level of deuterium. According to theory the component (2) consists of the two transitions $2^2P_{\frac{3}{2}}-3^2D_{\frac{5}{2}}$ and $2^2S_{\frac{1}{2}}-3^2P_{\frac{3}{2}}$, the former having 2.4 times the intensity of the latter. Hence, if the 2^2S level is displaced by an amount x cm^{-1}, the component (2) will undergo an apparent displacement of approximately $0.3x$. On the other hand, the component (3) consists of the transitions $2^2S_{\frac{1}{2}}-3^2P_{\frac{1}{2}}$ and $2^2P_{\frac{1}{2}}-3^2S_{\frac{1}{2}}$, the former being 10.7 times as intense as the latter. Thus its apparent displacement is $0.9x$. Consequently the separation of components (1) and (2) is decreased by an amount $0.3x$, whereas the separation of components (3) and (2) is increased by $0.6x$. This agrees fairly well with the results of Williams, and of Houston and Robinson, if the displacement x is taken to be about 0.03 cm^{-1}.

An S level displacement of this magnitude checks quite well with discrepancies observed in the doublet separations of other Balmer lines of hydrogen, as is seen from Table I.

TABLE I.

	Hα	Hβ	Hγ	Hδ	Hϵ
$\Delta\nu_{\text{theor}}$	0.319	0.344	0.353	0.358	0.360
$\Delta\nu_{\text{obs}}$	0.307	0.330	0.339	0.345	0.351
$\Delta\nu_{\text{corr}}$	0.308	0.330	0.339	0.343	0.345

The first two rows are the separations in cm^{-1} of the apparent centers of intensity as given by Houston and Hsieh.[4] The third row contains the theoretical separations obtained if a $2S$ level displacement of 0.030 cm^{-1} is assumed.

A displacement of the S levels would seem to point toward some perturbing interaction between the electron and the nucleus. As was indicated by Kemble and Present, the interaction required is much too large to be accounted for by the assumption of a finite size of electron and proton. An estimate of the magnitude of the interaction can be obtained by superposing on the Coulomb field a simple repulsive potential of height D, extending for a distance of r_0 cm from the nucleus. A first-order perturbation treatment raises the energy of the n^2S level of a hydrogen-like atom by an amount

$$\frac{4}{3}D\frac{Z^3}{n^3}\frac{r_0^3}{a_0^3},$$

where a_0 is the Bohr radius. If we assume a displacement of the $2S$ level of deuterium of about 0.3 cm^{-1}, as suggested by Williams' results, we find that Dr_0^3 must be about 5×10^{-43} erg cm^3. Thus if r_0 were taken to be the nuclear radius, 3×10^{-13} cm, D would have to be given the extremely high value of about 100 Mev.

In the case of the ionized helium line λ4686, an S level displacement would shift two of the weaker components toward the red, but would not affect the two main components, which involved transitions between P, D and F levels. Measurements by Leo[5] and by Paschen[6] show deviations from the theoretical values for the two weak components which could be explained by a 3^2S level displacement of 0.04 or 0.05 cm^{-1}. Results soon to be published by Chu, however, show no deviations of this magnitude.

An S level displacement could also be the cause of a slight shift toward the red observed by Edlén[7] in the doubly-ionized lithium line $1s^2S-2p^2P$.

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[1] Houston and Hsieh, Phys. Rev. **45**, 263 (1934); Williams and Gibbs, Phys. Rev. **45**, 475 (1934); Kopfermann, Naturwiss. **22**, 218 (1934); Spedding, Shane and Grace, Phys. Rev. **47**, 38 (1935); Houston, Phys. Rev. **51**, 446 (1937).
[2] Kemble and Present, Phys. Rev. **44**, 1031 (1932).
[3] Williams, Phys. Rev. **54**, 558 (1938).
[4] Houston and Hsieh, reference 1.
[5] Leo, Ann. d. Physik **81**, 757 (1926).
[6] Paschen, Ann. d. Physik **82**, 689 (1927).
[7] Edlén, *Wellenlängen und Termsysteme zu den Atomspektren der Elemente* Li, Be, B, C, N, O (Uppsala, 1934), p. 29.