Letters to the Editor.

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A New Connexion between the Absorption Spectrum of Hydrogen and the Many Lined Spectrum.

It will be recalled that Dieke and Hopfield showed that the absorption bands of H_2 , which are located in the extreme ultra-violet (about 1000-1500 Å.), were due to transitions up from the ground level of H_2 , which they called A , to two higher electronic levels which they called B and C respectively. Two years ago I found the emission bands in the visible which go down to the B , or 2^1S , level. In a series of papers (*Proc. Roy. Soc., A*, vol. 123, pp. 54, 466; vol. 124, pp. 50, 69; vol. 125, p. 23; 1929) Dr. Davidson and I have been able to show that these bands comprise a large number of distinct band systems and contain a very large part of the total strength of the visible emission spectrum of H_2 . Various attempts have been made from time to time to discover bands in this spectrum which end on Dieke and Hopfield's C level, but, until recently, nothing at all convincing has resulted from these efforts.

I have now found a number of band systems which end on this C state. These systems all have initial states which are identical with one or other of the initial states of the bands ending on the 2^1S level. Most, though not all, of the bands are weak, but there is no doubt about their authenticity as the frequencies of the lines are connected by combinations which are known with great accuracy. The initial levels from which the transitions arise are those denoted by Richardson and Davidson as 4^1A , 4^1B , 4^1C , $4^1\chi$, 4^1E , 3^1A , 3^1C , and 3^1O . Possibly 3^1K , 3^1L , 3^1N , and $1Q$ may have to be included in this list, but there seem to be no bands coming from $4^1\Psi$, 3^1B , and 3^1M . So far as they have been investigated, the band systems have the character of band sequences similar to those of the α , β , and other systems ending on 2^3S rather than the progression character of the bands ending on 2^1S . The bands which arise from the initial states to which the electronic quantum number 4 has been assigned lie in the green, the others in the infra-red.

The bands all have P' , Q , and R' branches, but these are not equally developed. Most of them resemble the α , β , etc., bands in having the Q branches strongest, R' intermediate, and P' weakest, but the bands starting from 4^1E have R' stronger than Q . The lines in each band have an alternation in intensity corresponding to a ratio in the weights of the alternate states of about 3 to 1. The stronger lines are Q_2 , Q_4 , R'_3 , R'_5 , P'_3 , P'_5 in my numbering, which is one unit higher than that used by Hori and others. The transitions are governed by the same exclusion rules as operate in the other band systems of H_2 . The doublet differences due to the non-coincidence of the $R' P'$ with the Q final levels increase rapidly with rotational energy.

The final term differences, both vibrational and rotational, agree with those of Dieke and Hopfield's C level to the accuracy of the ultra-violet data, and the analysis of the final level confirms the correctness of Hori's analysis of the Werner ($C \rightarrow A$) bands. This is important for several reasons, but I shall mention only one. It shows that this C level is something different from the initial level of Richardson and Davidson's infra-red bands. This initial level is quite distinct from the final level of the α , β , etc., bands, and both these levels have total (electronic) quantum number 2.

There is also in the initial level of the bands originally called $3^3S \rightarrow 2^3S$ by Richardson and Das what is almost certainly another 2 level. We thus have certainly 4, and probably 5, 2 levels in the spectrum of H_2 . It is impossible, on any accepted principles, to classify all these 2 levels as singlet levels (or all as triplet levels). I therefore think that these new results greatly strengthen my view that the α , β , etc., and the $3^3S \rightarrow 2^3S$ bands should be assigned to the orthohelium-like (triplet) systems, and all the other known band systems to the parhelium-like (singlet) systems.

I think it probable that the following classification of a number of the more important levels will turn out to be correct: *Parhelium-like (singlet) levels.* $A = 1\sigma^1\Sigma$, $B (= 2^1S) = 2\pi^1\Sigma$, $C = 2\pi^1\Pi$ (= final level of present systems), infra-red $= 2\sigma^1\Sigma$, $3^1O = 3\sigma^1\Sigma$, $3^1C = 3\delta^1\Sigma$, 3^1A and $3^1B = 3\delta^1\Pi$, $1Q$ and the progressions about $\lambda 4200 = 3\delta^1\Delta$, $4^1E = 4\sigma^1\Sigma$, $4^1C = 4\delta^1\Sigma$, 4^1A or 4^1B (possibly both) $= 4\delta^1\Pi$, $4^1\chi = 4\delta^1\Delta$. *Orthohelium-like (triplet) levels.* Lower levels of α , β , etc., bands $= 2\pi^3\Sigma$, upper levels of these bands $= m\pi^3\Pi$ ($m=3, 4$, etc.), upper levels of the $3^3S \rightarrow 2^3S$ (or $3^3S' \rightarrow 2^3S$) bands $= m\sigma^3\Sigma$ ($m=2, 3$). It would take too much space to defend this classification in detail, but a complete account of these systems and the conclusions to be drawn from them will be published elsewhere. For other views, reference may be made to a recent communication in NATURE by Dieke (June 29, 1929, p. 979) and to articles in the *Zeitschrift für Physik* by Weizel and by Finkelburg and Mecke. It may be permissible to add that the number of established electronic levels in H_2 is now about forty.

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Relationship between h , c , and e^2 .

I HAVE been trying to find experimental or indirect evidence bearing on Prof. Eddington's suggestion (*Proc. Roy. Soc., Jan. 1929*) of the relationship

$$\frac{ch}{2\pi e^2} = 136. \quad (1)$$

For six quantities such as the six fundamental quantities c , e , h , G , m , and M (the 'mass' of the proton), I find that the *a priori* chance of there being a non-dimensional product or quotient of any three or less of the quantities, of which one may be raised to the second power, is between 1:1 and 1:5. Two such products are, however, found, namely, ch/e^2 and M/m . Further, assuming the approximate order of magnitude of the six quantities, the chance of a product chosen at random falling between 2000 and 1/2000 in value is about 1:7. But the values found are 860 and 1840 approximately. It is not, therefore, easy to attribute these results to chance.

On the other hand, if the non-dimensional constants 860 and 1840 are like those that usually occur in physics, I have shown (*Phil. Mag.*, April 1929) that they are only to be expected once in about 860 and 1840 such constants, respectively. Amongst 1125 constants I have only found one so large as 316; and the only case that I remember comparable with those now considered is the Reynolds number referring to flow through a straight tube just ceasing to be turbulent. The magnitude of the numbers is illustrated by the complexity of the suggestions $2\pi(5+2^4) = 2\pi \cdot 136$; and $(1^2 + 2^2 + 2^2 + 3^2 + 3^2 + 4^2)^2 = 1849$ (see Enos E. Witmer, NATURE, Aug. 3, p. 180).

Apart from the experimental evidence given by Millikan's work, tending to show that the number in equation (1) is not exactly 136, there is similar evidence given by Bohr's theory for the Balmer series. Thus, writing Rydberg's constant for hydrogen

$$1.0968 \times 10^5 = \frac{2\pi^2}{c(1+m/M)(e/m)} \cdot \frac{e^5}{h^3} \quad (2)$$

(e being in e.s.u.), and eliminating h between (1) and