11. NOTE ON THE SECONDARY SPECTRUM OF HYDROGEN[*]

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In recent years the problem of the Secondary Spectrum[1] of hydrogen has again come to the forefront, on account of the interest which attaches to it with regard to Bohr's theory of quantum emission of spectral lines. Theoretical physicists are inclined to ascribe the Secondary Spectrum to the molecule of hydrogen, the Primary Spectrum being due to the atom. On the other hand, many experimental physicists are by no means satisfied by the explanation offered, but on the basis of the experiments of Fabry and Buisson[2], the opinion is sometimes expressed that at least a part of the secondary spectrum may be due to the H-atom.

But a closer perusal of the above-mentioned works of Fabry and Buisson shows that probably proper interpretation has not been put on their experimental results. In their experiments the mass of the radiation centres was calculated from the limit of visibility of the line in question in the Fabry-Perot interferometer according to the formula

$$\frac{\triangle}{\lambda}=A\sqrt{\frac{M}{\theta}},$$

where $\triangle$=limit of visibility, M=weight of the radiating centre in terms of the H-atom as unity, θ=absolute temperature, A is a constant.

Fabry and Buisson found that for the red line $H_\alpha=6563$, $\frac{D}{\lambda}=50{,}000$, while for a secondary line (not mentioned) $\frac{D}{\lambda}=72{,}000$.

The value of A was taken from theoretical papers by Lord Rayleigh[3] and Schönrock.[4] Thus they obtained $M=1$ for the secondary line (approximately), but a much smaller value—probably (.5)—for the H_α line.

Since the second value is impossible, they concluded that in both cases $M=1$, the value of $\triangle$ for H_α being considered unreliable, because H_α is a double line, and it is rather difficult to determine its limit of interference.

But it has been shown in a paper published in the Physical Review[5] that the value of A is subject to fluctuations depending upon the silvering of the mirrors, the definition of visibility and other causes. In the papers of Lord Rayleigh and Schönrock the value of A is calculated from two interfering beams only, while in the Fabry-Perot apparatus we have to do with an infinite number of interfering beams. Hence no absolute reliance can be placed upon a theoretically deduced value of A.

Since for a certain particular apparatus A has a definite value, the best interpretation of Fabry-Perot and Buisson's results seems to be the relative estimation of the masses of the radiating centres in the two cases. We thus have

$$\sqrt{\frac{M_2}{M_1}}=\frac{72{,}000}{50{,}000}=1.4 \text{ or } M_2=2M_1 \text{ (approximately)};$$

i.e., the mass of the radiating centres responsible for the emission of a secondary line is twice the mass of the radiating centres emitting H_α. In other words, according to the interpretation given here, the experiments prove the contrary of what is generally deduced from them—viz., if the H_α-line is emitted by an H atom, the secondary lines are emitted by the H molecule.

It is to be hoped that the problem may again be experimentally attacked.

On the theoretical side the difficulty is not only mathematical, but also physical. We have not as yet any mechanical model before us visualizing in a satisfactory manner the coupling of two Bohr atoms into an H-molecule. In the Bohr-Debije model the individuality of the component atoms is entirely lost[6]. This is a serious theoretical objection which has not yet been overcome.

Nicholson[7] has already calculated, on the basis of Bohr's theory, the radiation from a Bohr model, consisting of a single nucleus and two electrons. But none of the calculated lines agree with any of the observed secondary lines.

I tried to calculate the radiation from a system consisting of two fixed positive centres[8], and one electron, on the lines of Sommerfeld's generalisation of Bohr's theory. It would give, it was expected, the radiation from a positively charged H-atom. The complete mathematical solution of this problem has already been given by Jacobi[9]. The quanta-integrals come out in terms of elliptic integrals of the first, second, and third kind, but it has not yet been found possible to extricate the energy out of these functions, and express it in terms of the quanta-numbers.

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[*] Communicated by the Author.

[1] For example, Merton, Proc. Roy. Soc. Lond., vol. xcvi. p. 382; Lenz, *Ber. d. Ph. Gesellschaft*, pp. 632-643 (1919).

[2] Fabry and Buisson, *Journal de Physique*. pp. 435-445 (1912).

[3] Lord Rayleigh, *Phil. Mag.*, vol. xxvii (1889).

[4] Schönrock, *Ann. d. Physik*, vols. xx & xxii. (1906).

[5] Saha, *Phys. Rev.*, Dec. 1917.

[6] Len, *Ber. der Deutsche Physikalische Gesellschaft*, pp. 632-643 (1919).

[7] Nicholson, Month. Not. Roy. A. S. Vol. lxxix, (1919).

[8] This incomplete paper was communicated to the Indian Science Congress held at Bombay in January 1919. I find in the January No. of the *Phil. Mag.* that Dr. Silberstein has traversed the same ground and arrived at identical mathematical results, but this paper likewise contains no reduction of the energy-expression to quanta numbers.

[9] Jacobi, *Vorlesungen über Mathematik*, Article 28-30. Appel, *Traité de Mécanique Rationelle*, Tome ii. p. 407 *et seq.*