Physics. — *Excitation of the secondary and the Balmer spectrum of Hydrogen by electronic impact in molecular Hydrogen and by protons of high velocity.* By L. S. ORNSTEIN, A. A. KRUITHOF and W. A. M. DEKKERS. (Communication from the Physical Laboratory of the University Utrecht).

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A study of the excitation of the secondary spectrum of Hydrogen is of importance in view of the classification of this band spectrum. The normal state of the molecule is a singlet state, therefore the way in which the excitation function of singlet and triplet bands depends on the velocity of the electrons could help to decide which bands are of one or the other type. The intensity of the Balmerlines excited in molecular hydrogen as a function of electronic velocity can furnish material for the knowledge of the type of the excitation.

The electrons were produced by a glow kathode with grid and shot into a hollow anode (field free space) provided with a grid. The first grid is used (like in the work of SCHAFFERNICHT) in order to get sufficient emission of electrons when through the second grid electrons with low velocity enter the field free space. Further the first grid is of great importance as it prevents stray electrons to enter the hollow anode. Fig. 1 gives the construction of the glow-kathode with the grids.

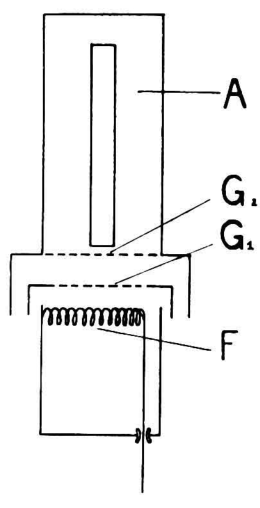

FIG. I

A Hollow anode with slit.
F Filament.
G_1 First grid.
G_2 Second grid.

The kathode, grid and hollow anode are mounted into a glass tube through which dry hydrogen gas is pumped.

The pressure of the Hydrogen is 0.03 mm; the current to the hollow anode 3 mA, the voltages by which the electrons are accelerated lie between 18 and 50 V.

The spectrum was photographed with a two prism spectrograph of high intensity and dispersion. Density marks were taken in the usual way; the plate sensitivety is eliminated with the help of a calibrated tungsten lamp. We have measured the following band lines Notation of MECKE (tables 1 and 2) and further H_β, H_γ and H_δ.

TABLE 1. Triplet bands.

Wavelength	Band system	branch	m	n'	n''	Wavelength	Band system	branch	m	n'	n''
4024.73	γ	Q	1	0	0	4554.15	β	Q	1	1	1
4159.30	β	Q	1	2	1	4562.22	β	Q	3	1	1
4490.45	β	Q	1	0	0	4617.54	β	Q	1	2	2

TABLE 2. Singlet bands.

Wavelength	Band system	branch	m	n'	n''	Wavelength	Band system	branch	m	n'	n''
3990.03	A	Q_1	2	3	2	4199.79	A	R_2	1	1	0
3997.14	A	R_2	2	3	2	4205.10	A	R_2	2	1	0
4043.57	C	P	4	2	0	4210.13	A	R_2	3	1	0
4082.38	A	R_2	1	2	1	4212.50	A	R_2	4	1	0
4087.76	A	R_2	2	2	1	4568.13	A	P_0	4	0	0
4171.31	A	Q_1	4	1	0	4572.71	A	Q_1	4	0	0
4175.17	A	Q_1	3	1	0	4575.88	A	P_0	3	0	0
4177.13	A	Q_1	2	1	0	4579.99	A	Q_1	2	0	0
4182.17	A	P_0	2	1	0	4582.59	A	P_0	2	0	0
4195.67	A	R_2	0	1	0	4627.99	A	R_2	0	0	0

If we draw the excitation curves — intensity of the lines as function of the voltage — the ordinates are proportional for the lines of the two groups of bands separately and for the Balmer-lines. In fig. 2 the mean curves for singlet and triplet lines in the secondary spectrum and for the Balmer-lines are given. We have reduced the curves at the same value for 23 Volt. The singlet lines under consideration are much stronger than the triplet lines.

The curves consist of two parts of very different behaviour: between 18 and 22 Volts there is a strong drop of the intensity with rising voltage but the curves coincide. Above 23 Volts they show a very different feature. Comparing in this part *S* and *T* curve we find the same form of the curves as was found for the Helium singlet and triplet lines. The excitation of the triplet is diminishing more rapidly than that of the singlet so that our results give a confirmation of RICHARDSON's classification compared with the former classification of MECKE.

Now we can compare the excitation curve for the Balmer-lines with that of the singlet bands taking the ratio at corresponding velocities.

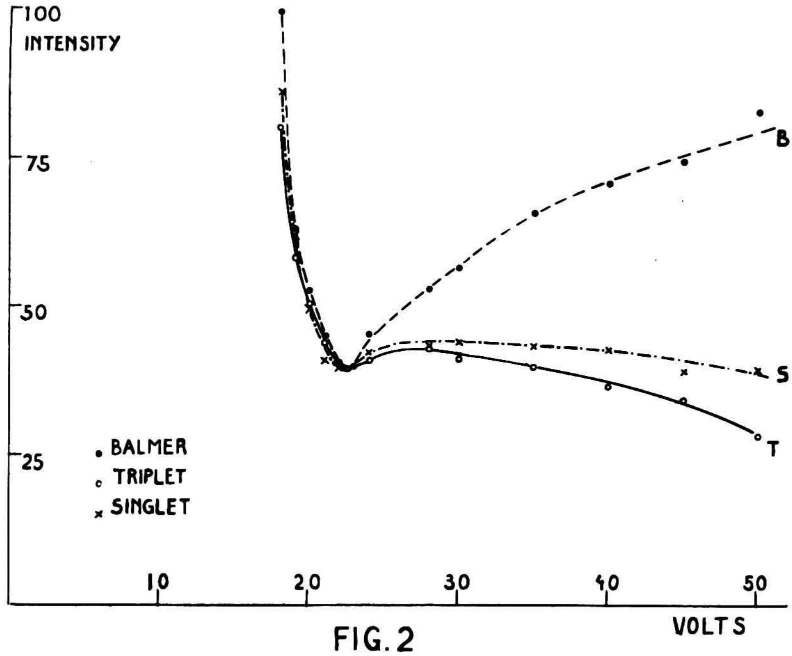

FIG. 2

Plotting this ratio against the voltage we find a straight line passing through the origin, so that we find that the ratio of Balmer and singlet

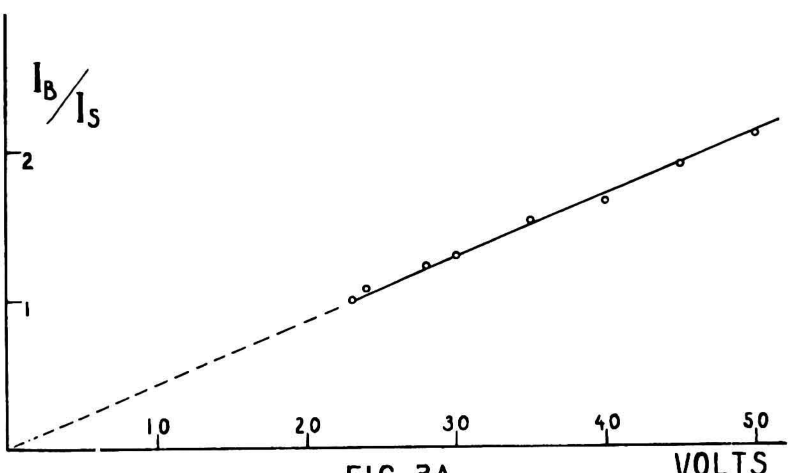

FIG. 3A

lines I_B/I_S can be represented for the region between **24** and 50 V. by an equation of the form

$$I_B/I_S = AV.$$

If we do the same with the triplet lines we get a strongly curved line.

Now it is interesting to compare the excitation function of the Balmer lines in molecular Hydrogen with the excitation curve found by ORNSTEIN and LINDEMAN for atomic Hydrogen. Plotting the ratio (fig. 3 B) of the

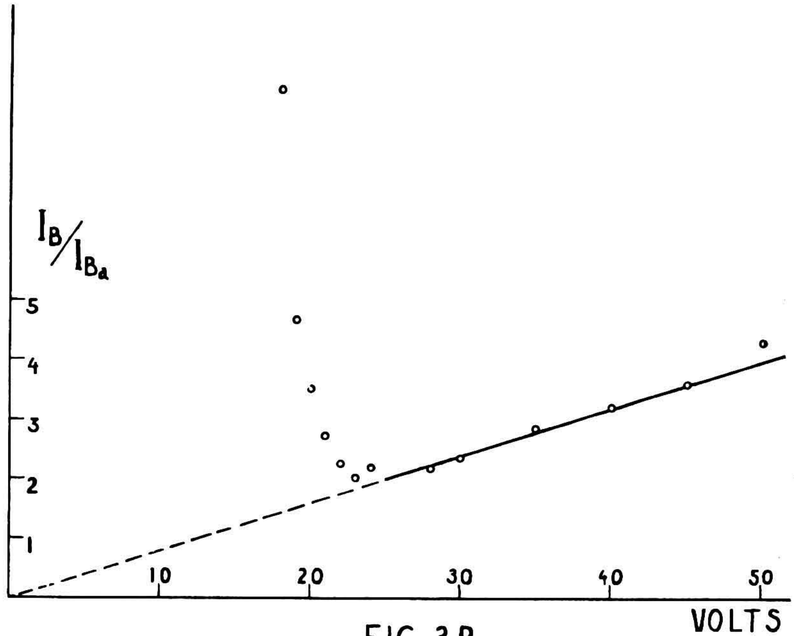

FIG. 3 B

intensities we find again a straight line through the origin, so that the ratio of the Intensity for Balmer lines in molecular Hydrogen I_B to the Intensity for those lines in atomic Hydrogen $I_{B.a}$ can be represented by:

$$\frac{I_B}{I_{Ba}} = BV.$$

It seems therefore that the excitation function of atomic Hydrogen and that for Singlet-Singlet transitions in molecular Hydrogen is about the same in the Voltage region under consideration.

It will be very interesting to investigate whether this simple relation holds through a larger field of velocities and to consider the way in which I_S and I_B depend on the current to the field free space. We could understand the result if the excitation of the atomic spectrum in molecular Hydrogen goes in two steps, the excitation of molecules to a proton, an electron and an atom (possibly for a part excited) and to excited molecule in singlet state, the proportion of the first being proportional to the electronic energy. But it is perhaps better not to speculate about this point before further measurements are available. If we extrapolate the V law for I_B/I_{Ba} we get the curve of fig. 4. Subtracting the part which in this way has to be ascribed to atoms we find a resulting excitation curve between 18 and 24 Volt. which still ought to be discussed.

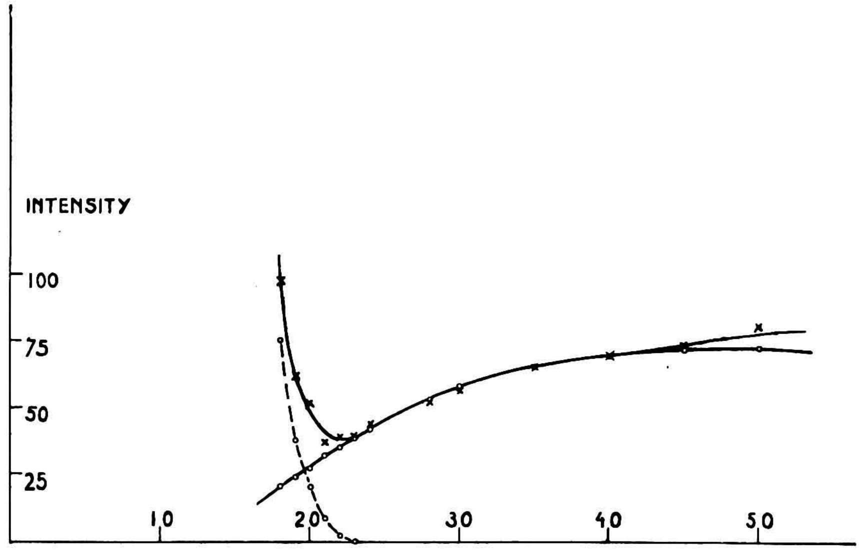

FIG. 4

There are strong reasons to ascribe this part of the excitation to protons which are formed between the first grid and the second and which escape to the hollow anode. There is the more reason to do it as still some light is seen in the field free space when there is no field between the grids. The fact that the intensity is stronger for lower electronic velocity could be interpretated such that for low electronic velocities the protonic velocities are higher or that the number of protons is changed so that the left component of the excitation curve represents a disturbed protonic excitation function.

In order to have some control of this hypothesis we changed the potentials in such a way that protons of velocities between 50 and 70 V. entered the field free space and we found now a very strong excitation ot S and T bands and also of the Balmer-lines. The proportion of the Balmer-lines for electronic and for protonic excitation was measured and compared. It amounts for both to: $H_\beta : H_\gamma : H_\delta = 13 : 3.1 : 1$. The results confirm that the first part of the curve must be ascribed to the impact of protons. In short we hope also to investigate further the excitation function for protons of known velocity in a larger region.

Utrecht, May 1931.