



XXXI. Compound line-spectrum of hydrogen

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To cite this article: R. S. Hutton B.Sc. (1898) XXXI. Compound line-spectrum of hydrogen , Philosophical Magazine Series 5, 46:280, 338-343, DOI: [10.1080/14786449808621200](https://doi.org/10.1080/14786449808621200)

To link to this article: <http://dx.doi.org/10.1080/14786449808621200>



Published online: 08 May 2009.



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of current flowing through the spark. This conclusion is in gratifying agreement with the work of Trowbridge and Richards*, who have similarly used the damping effect upon an oscillatory current to measure the resistance, but have done this by direct substitution.

3. It appears from Table IV. that when the secondary circuit is closed by a spark, the primary current decreases with the length of this spark; but the secondary current decidedly increases. This behaviour is not explained by the approximate theory here deduced, but was most unmistakable both in early preliminary work and in the later more careful determinations here recorded. It still remains to be shown whether this is due to the conditions of the experiment, or is to be explained by a more accurate application of theoretical reasoning.

In conclusion, it only remains for me to express my thanks to Professor A. G. Webster for his unfailing sympathy and helpfulness, which has rendered this work possible, and to Clark University which placed at my disposal the facilities for the work.

XXXI. *Compound Line-Spectrum of Hydrogen.*

By R. S. HUTTON, B.Sc.†

1. *Introduction.*

THE general conclusion arrived at by spectroscopists with regard to the compound line-spectrum of hydrogen is that it really belongs to the element, and not to a hydrocarbon as was at one time supposed. Nevertheless the question cannot be said to be absolutely proved, especially in view of Cornu's experiments, which seemed to indicate that if the vacuum-tubes have been previously washed out with oxygen, the compound line-spectrum disappears, or at any rate becomes much weakened. It seemed to me to be of utility to repeat Cornu's‡ experiments in a different form, and also to prepare the hydrogen by methods different from those in common use.

2. *Fractionation of the Hydrogen occluded by Palladium.*

It first occurred to me that good results might be expected by carefully fractionating off the hydrogen absorbed by palladium§; and although my attention was shortly after

* Phil Mag. (5) xliii. pp. 349-367 (1897).

† Communicated by Arthur Schuster.

‡ A. Cornu, *Journ. de Phys.* ii. 5. pp. 100-103 & 341-354 (1886).

§ I was able to make use of this method by the great liberality of Messrs. Matthey in lending me 50 grams of palladium-foil, gratitude for which I wish to express here.

called to Randall's paper (*Am. Chem. Journ.* vol. xix. p. 682, 1897), my method seemed to have advantages not possessed by his, and I was consequently encouraged to proceed.

The hydrogen was prepared by Bunsen's method--the electrolysis of dilute sulphuric acid combining the oxygen with zinc amalgam; very carefully purified chemicals and apparatus were employed. In order to ascertain the amount of hydrogen with which the palladium was charged, observations were made of the quantity of electricity used for electrolysis.

The palladium was used in the form of foil, and, as suggested by Graham, was first heated to a high temperature, oxygen being passed over it to ensure that any carbonaceous matter should be oxidized: this of course caused some surface-oxidation; but on passing a current of hydrogen over the heated metal and absorbing the moisture, the palladium was left in a suitable condition. The palladium contained in a suitably constructed glass tube was charged with hydrogen by passing a current of gas over the metal previously heated to a very high temperature, and in this way in a short time the tube was freed from the last traces of air; a stopcock just in advance of the palladium-tube was then closed and the metal gradually cooled in hydrogen, which it thus absorbed to a known amount; after which connexion with the hydrogen-generating apparatus was cut off by fusing off the connecting tube.

The palladium-tube was in connexion with a small drying-tube (containing potash which had previously been heated to a high temperature in a silver dish and cooled in a desiccator), and through this with the spectrum-tube and another drying-tube and thence to the pump; the spectrum-tube was also in connexion with a tube containing potassium permanganate which on heating gave very pure oxygen.

The spectrum-tube, which was of the ordinary "end-on" description but with the wide tubes longer than usual (to keep the platinum--thrown off by the electrodes--away from the capillary), was constructed conveniently so that the entrance and exit tubes for the gas were near the electrodes. In this way, even at very small differences of pressure, the fresh gas quite displaced that previously in the tube.

Having first been thoroughly heated with oxygen, the vacuum-tubes were exhausted several times with similar treatment until the spectrum of quite pure oxygen was alone seen, this being taken as a criterion of the condition of the tube. A very high vacuum having been obtained, connexion was made with the palladium-tube and a current of hydrogen caused to

flow through the vacuum-tube by continuing the action of the pump. In this way it was possible to fractionate off the hydrogen. Although the work was carried out with as great care as possible, I was unable to detect any difference in the spectrum of the fractionated gas notwithstanding that the method was varied. The compound line-spectrum was extremely bright all the time, at any rate until a fairly high vacuum had been obtained, and working under pressures between 2 and $\cdot 1$ millim. the second spectrum was always very evident; the colour of the discharge in the capillary was mostly of a greyish-blue colour and never red.

3. Influence of Presence of Traces of Oxygen upon the Hydrogen Spectrum.

Special precautions had been taken to prevent carbonaceous contamination, the lubrication of all the Geissler mercury-trapped taps being effected with phosphoric acid. Still I thought it might be possible to find if any hydrocarbon were present or not by introducing a little oxygen into the spectrum-tube containing hydrogen, and then making observations for the carbon spectrum. The introduction of oxygen was effected by warming the permanganate-tube mentioned above; but although I repeated the experiment many times, no carbon spectrum was to be seen. It was most remarkable, however, that so soon as the oxygen reached the tube the colour of the discharge in the capillary changed to a very bright red; and under these conditions it was possible almost entirely to get rid of the second spectrum, or at any rate it was so very dim in comparison with the principal lines that it could not be detected visually.

These observations were confirmed in many separate experiments, photographs of the spectrum being also taken. It was most noticeable in each case that the sudden change took place; and although in the photographs, some of which had 25 minutes exposure, all the brighter lines of the second spectrum came out dimly, the background of continuous spectrum, which seems generally to accompany this second spectrum, was quite absent.

I next tried sparking with magnesium electrodes to make sure that the excess of oxygen had been removed, and in this way the red colour of the discharge was not altered; and other experiments, in which several fresh additions of hydrogen were made to the tube without causing the disappearance of the red colour, lead me to think that the amount of oxygen necessary is very small.

This sudden change from the bluish colour to the red seems

to be very similar to that mentioned by Trowbridge and Richards (*Phil. Mag.* [5] xliii. p. 137); the continuous discharge from their high-tension accumulator gave a whitish glow in the capillary which gave the second spectrum:—"A large capacity is needed to change this spectrum into the familiar 4-line spectrum. . . . The change is marked by a sharp alteration in the colour of the glow from white to deep red." It seems possible, therefore, that the presence of oxygen alters the electrical conditions, and that this alone accounts for the sudden change.

It is not easy to find from Cornu's paper exactly how pure a spectrum he obtained; however, he says:—"Dans ces tubes ainsi purifiés l'éclat des raies de l'hydrogène est vraiment admirable." But in this connexion it should be noted that this may have been due to the presence of traces of oxygen, since Cornu washed out his tubes with ionized oxygen, and the arrangement which he used makes it quite possible that the hydrogen afterwards admitted might become contaminated with traces of this gas; at any rate precautions to guard against this contamination are not described in his paper.

Stas has noted, in one of the papers published since his death, that extraordinary precautions have to be taken to remove a trace of some impurity which is present in all hydrogen prepared by the usual methods (see J. S. Stas, *Œuvres Complètes*, Bruxelles, 1894, iii. pp. 216, 225); and the possibility of this unknown impurity having some influence upon the spectrum needs perhaps to be considered.

I was sorry to be unable to continue the work upon the influence of oxygen upon the hydrogen spectrum, as probably some more conclusive result might have been arrived at.

4. *Spectrum of Hydrogen prepared by a different Method.*

On studying the work which has been done not only on the spectrum, but also with regard to the other properties of hydrogen, one cannot help being struck by the fact that very few workers have attempted to prepare this gas except by methods which are essentially the same, in nearly all cases by the decomposition of water or of a solution of an acid in water; and, so far as I can find out, the gas prepared from sources quite different has not been worked with. Various methods suggested themselves by which at least small quantities of hydrogen might be prepared, but the one I adopted recommends itself more by its dissimilarity from that usually employed than by its simplicity. I decided to prepare hydrogen from pure ammonia gas, generated by heating ammonium chloride purified by Stas' method with lime prepared from marble. The ammonia thus formed remained in

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contact with powdered caustic soda, to dry it well. The decomposition of the gas was effected by red-hot platinum, through which the hydrogen formed was allowed to diffuse into a vacuum. The platinum was in the form of a closed tube provided with a long narrow neck, the whole being in one piece, and very beautifully made for me by the further kindness of Messrs. Matthey. The end of the narrow tube was connected by fusion with glass tubing, and thus with the spectrum-tube, pump, &c.

In this way quite a large amount of hydrogen was diffused through the platinum, three separate experiments being performed; but the hydrogen gave to all appearances a spectrum identical with that obtained from the hydrogen absorbed by palladium. I feel that particular value is attached to this experiment, simple as it may seem, since great care was exercised in designing the apparatus, and many precautions adopted which it is impossible to detail without making the description excessively long. It is perhaps sufficient to say that the platinum-tube was enclosed in a glazed porcelain tube, into which after evacuation the ammonia was generated; the porcelain tube was heated in a specially arranged muffle-furnace.

My results, as far as they go, support therefore the generally accepted conclusions that this second spectrum is a true hydrogen spectrum, and render it probable that Cornu's results may be explained by the fact that traces of oxygen remained in his tube, such traces almost completely destroying the compound spectrum.

The above experiments were carried out in the Physical Laboratories of the Owens College.

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XXXII. Note on Mr. Sutherland's Objection to the Conclusiveness of the Michelson-Morley *Æther* Experiment.

To the Editors of the *Philosophical Magazine*.

GENTLEMEN,

I HAVE just seen a paper by Mr. W. Sutherland in your number for January this year, where he suggests reasons for doubting the trustworthy character of the negative result of Michelson and Morley's great experiment. It might, for instance, be attributed to the possible second-order influence of a hitherto neglected first-order tilting or shifting of the wave-fronts brought about by the undiscovered drift of the æther past the earth. (I am not sure that Mr. Sutherland means exactly this; but if not his meaning is unintelligible, having regard to the way in which the experiment was actually performed, viz. by revolving a floating stone and observing in all azimuths. A criticism by Mr. Sutherland is, however, always of importance.)

But in my memoir on Aberration (*Phil. Trans. A.* 1893, pp. 739, 748, & 790) I have shown that though motion of the entire medium can readily affect *waves*, it has no first-order effect upon *rays*, neither upon their path nor their time of journey; and inasmuch as it is either ray-path or time of journey which is observed in any optical experiment, I am unable to perceive any flaw in the Michelson-Morley result, that the expected second-order effect is also *nil*. It might be thought that the varying inclination of the ray to the mirror at different