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The Spectrum of Magnesium Hydride

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XVII. *The Spectrum of Magnesium Hydride.*

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[Plates 12, 13.]

Introductory.

In a paper communicated to the Royal Astronomical Society in June, 1907, I gave a preliminary account of my identification of a number of hazy "band lines" in the spectra of sun-spots with lines composing the green fluting in the spectrum of magnesium hydride.* Previous observations had suggested that the origin of these lines was most likely to be traced by the examination of fluted spectra, but numerous measurements of the flutings of substances such as vanadium and titanium, the lines of which are specially prominent in the spot spectrum, gave only negative results.† In December, 1906, however, Mr. Newall published an account of some observations of sun-spots in which reference was made to a probable dark fluting beginning at 5210·2 or 5211·0,‡ and this observation recalled the principal fluting of magnesium hydride with which I had long been familiar. No sufficiently precise measurements of the components of the fluting were then available for a satisfactory comparison, but new determinations of wave-lengths, based on a large-scale photograph taken for the purpose, left no doubt as to the identity of the stronger components with the principal band lines of the spots in the region considered. It seemed probable that several hundreds of these band lines would eventually be accounted for by magnesium hydride, and that the problem presented by the highly complex spot spectrum would be greatly simplified if the part due to the flutings could be completely eliminated.

The present paper gives an account of a more complete investigation of the

* 'Monthly Notices,' vol. 67, p. 530 (1907).

† 'Trans. Internl. Union Solar Research,' vol. 1, p. 217 (1906).

‡ 'Monthly Notices,' vol. 67, p. 170 (1906).

magnesium hydride spectrum, and includes a table of wave-lengths for the three principal flutings, which it is believed will be of service to those who are engaged in the reduction of photographs of the sun-spot spectrum.

Methods of Producing the Spectrum.

The magnesium hydride spectrum appears to have been first observed and investigated by LIVEING and DEWAR in 1878.* In the course of their experiments on the reversal of metallic lines, these observers recorded an absorption "line" near 5210 (corresponding to the first head of the green fluting), and concluded that it must be attributed either to magnesium or to magnesium together with hydrogen. The same "line" was afterwards observed in the spectrum of the spark between magnesium points in an atmosphere of hydrogen,† the line being most constantly visible when no jar was employed. With a small Leyden jar in the circuit, the line was still visible, but it was not seen continuously when a large jar was used until the pressure of the hydrogen, and its resistance, were very much reduced. In these experiments the fluted character of the spectrum was clearly brought out.‡

In another paper§ it was further remarked that the line 5210 and the series of fine lines which accompany it were sometimes seen in the flame of burning magnesium, but appeared with increased brilliance if the burning magnesium were held in a jet of hydrogen, of coal gas, or of steam.

The spectrum has also been investigated to some extent by Sir NORMAN LOCKYER,§ whose observations were chiefly made on magnesium ribbon burning in the interior of a Bunsen flame. This is, perhaps, the readiest method of producing the spectrum for observation with small instruments, but is unsuitable as a source intended for photography with high dispersion.

The most convenient source which I have yet found is the electric arc between magnesium rods in an atmosphere of hydrogen, preferably at from 1 to 3 inches pressure. The spectrum is also well seen if the arc be simply passed in an exhausted globe, as a sufficient supply of hydrogen is liberated from the heated poles after a few minutes' running.|| In this way the spectrum is obtained sensibly free from impurity lines, and shows little more than the lines of magnesium (and sometimes those of hydrogen) in addition to the flutings of the hydride.

The construction of the apparatus employed for this experiment will be gathered from fig. 1. A glass receiver of 2 or 3 litres capacity was selected, having 2 necks, and a side tube about 6 inches in length, which was closed by a plate of glass or quartz. The lower pole-piece was attached to a narrow brass tube passing through a

* 'Roy. Soc. Proc.,' vol. 27, p. 352 (1878).

† 'Roy. Soc. Proc.,' vol. 27, p. 494 (1878).

‡ 'Roy. Soc. Proc.,' vol. 30, p. 96 (1880).

§ 'Roy. Soc. Proc.,' vol. 30, p. 27 (1879); vol. 43, p. 122 (1887).

|| FOWLER and PAYN, 'Roy. Soc. Proc.,' vol. 72, p. 254 (1903).

rubber stopper which fitted tightly into the lower neck of the flask. The upper pole was attached to a similar brass tube and rubber stopper, but in order to allow of the manipulation of the arc, the stopper was not placed directly into the upper neck of the flask, but was connected with it by a wide rubber tube about 4 inches in length, kept stretched by a spiral spring inside it. The upper tube was connected with the

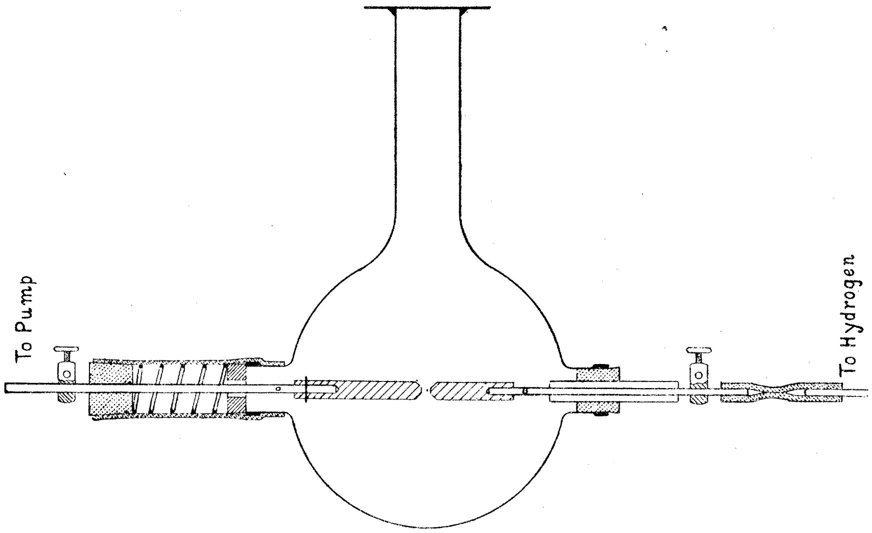


Fig. 1. Apparatus employed for arc *in vacuo*, hydrogen, or other gas.

pump and the lower one with the gas supply, communication with the interior of the globe being made through small apertures drilled in the brass tubes near the pole-pieces. This arrangement was found quite satisfactory so long as the apparatus was not allowed to become overheated, and intermittent exposures extending over several hours could be made before the window through which the arc was viewed became too clouded for further use. The current ordinarily employed was from 2 to 6 amperes, derived from the 110-volt lighting circuit, and showing a potential difference of 40 volts between the poles.

A convenient method of producing the spectrum has also been described by Mr. BROOKS,* who has obtained the flutings very brilliantly from a "high-frequency flame discharge" between magnesium ribbon spirals in hydrogen at low pressures. In a later paper† Mr. BROOKS refers to other experiments on the mode of production of this spectrum.

Considerations as to the Origin of the Flutings.

The outcome of the numerous experiments made by LIVEING and DEWAR was to indicate that hydrogen, in some form or other, was as necessary as magnesium for the production of the spectrum under consideration. Summarising their earlier results in

* 'Roy. Soc. Proc.,' A, vol. 80, p. 218 (1908).

† 'Astrophys. Jour.,' vol. 29, p. 177 (1909).

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

1880, these observers stated that "if it (the line 5210 at the head of the green fluting) be not due to a compound of magnesium with hydrogen, at any rate it occurs with special facility in the presence of hydrogen, and ought to occur in the sun if the temperature were not too high. We have been careful to ascribe this line and its attendant series to a mixture of magnesium and hydrogen rather than to a chemical compound, because this expresses the facts, and we have not yet obtained any independent evidence of the existence of any chemical compound of these elements."

Further important evidence was obtained later by LIVEING and DEWAR from a series of observations of the magnesium spark, without jar, in hydrogen at pressures above that of the atmosphere.* It was found that the flutings increased in brilliancy with the pressure, until at 15 to 20 atmospheres they were fully equal to the *b* group, notwithstanding that these had also increased in brightness. On letting down the pressure, the same phenomena occurred in reverse order, but the brightness of the flutings did not diminish so rapidly as it had increased. On introducing a large Leyden jar, when the pressure had again reached that of the atmosphere, the flutings were still visible, but with gradually diminishing intensity until the spark had continued for some time. In explanation of these observations, they wrote: "It appears that the compound, which had been formed in large quantity by the spark without jar at the higher pressures, is only gradually decomposed, and not re-formed by the high temperature of the spark with jar. This experiment, which was several times repeated, is conclusive against the supposition that the flutings are merely due to a lower temperature." Hence it was concluded that "the series of lines beginning at wave-length 5210 are due to a combination of hydrogen with magnesium, and are not dependent solely upon the temperature."

Since then the spectrum in question has been generally known as that of "magnesium hydride," and as no sufficient reason has appeared for assigning a different origin, this designation has been retained in the present paper.

I have at various times repeated many of the experiments described by LIVEING and DEWAR (but not yet including the spark under pressure), and have obtained results in complete accordance with those to which they referred. Additional observations made during the present investigation may also be mentioned. For example, when the arc was passed between magnesium poles in a nearly exhausted globe, no trace whatever of the hydride flutings was seen on first starting the arc, but the oxide group beginning at 5007 was a conspicuous feature of the spectrum. After 2 or 3 minutes' running, however, the oxide group entirely disappeared, while the hydride flutings gradually made their appearance and finally became very brilliant. These observations are most simply explained by supposing that the residual oxygen present in the globe at the beginning of the experiment was gradually consumed, forming magnesium oxide, while hydrogen was liberated when

* 'Roy. Soc. Proc.,' vol. 32, p. 198 (1881).

the poles became heated and entered into combination with the magnesium vapour in the outer parts of the arc. Other experiments have shown that hydrogen is occluded in considerable quantity in the metal, and, in fact, the C and F lines were often present in the spectrum, although no hydrogen was otherwise introduced into the globe. Attempts to completely expel the occluded hydrogen from the metal employed have not been successful.

In this experiment, if a high vacuum was first produced, the oxide bands were not seen at all, but the hydride spectrum gradually appeared as before. Again, when the residual air was first washed out by hydrogen, the hydride flutings were brilliantly visible as soon as the arc was struck, and the oxide flutings were not observed. When dry nitrogen at atmospheric pressure was introduced into the globe, neither the hydride nor the oxide flutings were seen. In hydrogen at atmospheric pressure the hydride spectrum was present, but was less bright than when the pressure was reduced.

In his earlier paper, Mr. BROOKS suggested that water vapour might be an essential factor in the production of the hydride spectrum,* and the experiment on the arc in hydrogen was accordingly repeated, with a quantity of phosphoric anhydride introduced into the globe. After standing for 24 hours, however, the flutings appeared at once on striking the arc, as in previous experiments, and with undiminished brightness. In fact, the absence of water vapour would seem to be sufficiently indicated by the absence of the oxide group 5007. Subsequent experiments made by Mr. BROOKS† have similarly led him to conclude that the presence of water vapour cannot be regarded as an essential condition for the production of the hydride spectrum.

All the experiments accordingly tend to show that magnesium and hydrogen are together concerned in the production of the flutings, and the simplest supposition is that they originate in the combination magnesium hydride. Assuming such combination of the two elements, it appears to take place directly under the influence of the arc, especially at low pressures, or of some forms of the spark discharge, or by the combustion of the metal in an atmosphere containing hydrogen either free or in combination.

It should be noted that the production of the hydride flutings is not the only effect of hydrogen on the magnesium arc spectrum. The enhanced lines also appear very prominently,‡ but they are especially developed close to the poles, while the flutings

* 'Roy. Soc. Proc.,' A, vol. 80, p. 223 (1908).

† 'Astrophys. Jour.,' vol. 29, p. 187 (1909).

‡ The enhanced lines which appear in the visible spectrum are 4481·31, and the pairs of lines for which the revised wave-lengths are 4434·20, 4428·20 and 4390·80, 4384·86. The polar localisation of these lines as compared with the flutings is particularly marked in a photograph taken with one pole of magnesium and one of iron. In another photograph, where the images of the poles appear to have been successfully kept off the slit, 4481 was relatively weak, and the feebler enhanced lines were wanting.

are not so restricted. Since these lines may be obtained in other ways, unaccompanied by the flutings, without the aid of hydrogen (as in the ordinary spark in air), it is probable that no chemical action is involved in their production in the arc in hydrogen. On the other hand, the flutings in question have only been produced in the presence of hydrogen, and since they may be obtained without direct electrical aid (as in burning the metal in a Bunsen flame), a chemical union of the two elements provides the most satisfactory explanation of the observations.

One of the chief objections to the above explanation of the flutings is that, although the spectrum may be easily produced, the compound itself has not yet been clearly recognised by chemists. WINKLER* possibly obtained it as part of a mixture resulting from heating magnesium with its oxide in an atmosphere of hydrogen, but no other chemical evidence of the existence of the compound has been brought forward. Further evidence has been sought by an analysis of the deposit formed by the passage of the arc in hydrogen. This consisted in part of thin spherical shells of magnesium, and partly of a fine black or dark grey powder, probably mixed, as a rule, with a small proportion of magnesium oxide. The analysis of this deposit was kindly undertaken by Prof. TILDEN, who reports that the volume of hydrogen given off on dissolving the sample supplied was always less than the amount calculated on the supposition that it was pure magnesium, and that there was no evidence of a hydride. This was, perhaps, only to be expected from the observation that there was no appreciable absorption of hydrogen during the passage of the arc, but there was the possibility that such absorption might be partly counteracted by the liberation of hydrogen from the heated poles.

In explanation of the spectroscopic observations, on the hypothesis that the flutings are produced by magnesium hydride, it may be supposed that a very small quantity of the compound is competent to produce a brilliant spectrum. The compound would not be unique in this respect, as the cyanogen flutings are ordinarily well developed in experiments on carbon compounds even if only a very small trace of nitrogen be present. Or it may be, as suggested by Mr. BROOKS, that the compound is in most experiments decomposed as quickly as it is formed. A perfectly definite conclusion does not at present seem to be possible.

The Spectrographs Employed.

For obtaining a general record of the visible spectrum, a small Littrow prismatic spectrograph, giving the region C to K on a plate $6\frac{1}{2}$ inches long, was employed. The photograph reproduced in Plate 12, No. 1, was taken with this instrument.

Numerous photographs were also obtained with a larger instrument of the same type, giving the region 6700 to 4700 on a 12-inch plate. A great deal of time was spent in reducing these photographs, using ROWLAND'S wave-lengths, but a concave

* 'Ber. Deutsch. Chem. Gesell.,' vol. 24, p. 1973 (1891).

grating of greater resolving power afterwards became available and the results were discarded.

The concave grating was ruled by ROWLAND, and has a radius of curvature of 10 feet, and a ruled space $3\frac{1}{4}$ inches by $1\frac{5}{8}$ inches. It was mounted temporarily as a Littrow spectrograph by Mr. EAGLE, and the photographs were taken on plates 12 inches by $2\frac{1}{2}$ inches. In the first order, the dispersion is about $5\frac{1}{2}$ tenth-metres to the millimetre, but in this method of using the grating the spectrum is not a normal one. Excellent photographs of the first-order spectrum were obtained with exposures ranging from 5 to 90 minutes, and the definition was very satisfactory. Photographs have also been taken in the second order, showing the principal lines of the green and blue flutings, but giving no impression of the fainter fluting in the yellow green.

A general record of the ultra-violet spectrum, extending to 2300, has been obtained by the use of a Hilger quartz spectrograph having one prism of 60 degrees.

General Description of the Spectrum.

When observed with small or moderate dispersion (Plate 12A, No. 1), the spectrum of magnesium hydride, as remarked by LIVEING and DEWAR, is somewhat similar in general appearance to the carbon ("Swan," or candle flame) spectrum, and the respective flutings occupy nearly the same parts of the spectrum. In each case the brightest fluting is in the green, and there are fainter ones in the yellow-green and blue, the first heads of the carbon flutings being at 5635·4, 5165·3, and 4737·2, while those of magnesium hydride fall at 5621·6, 5211·1, and 4844·9. Further, there is a fluting of simple structure at 4311 in the hydrocarbon spectrum, and a somewhat similar fluting of magnesium hydride at 4371·8.

On more minute examination, however, the resemblance is less close than might at first appear. Even under moderate dispersion the blue flutings in the two spectra are clearly of different structure, and they have practically nothing in common when the dispersion is great. The green and yellow-green flutings in the two spectra resemble each other in showing three or four heads, but whereas in the case of carbon the secondary heads persist under high dispersion, those of magnesium hydride are soon lost in the general mass of lines as the dispersion is increased.

From the extreme visible red to the beginning of the yellow-green fluting at 5621 the spectrum consists of a great number of faint lines, showing no heads sufficiently pronounced for measurement as such, though the lines are by no means equally spaced. (The carbon arc shows a very similar appearance in this region.) The yellow-green fluting begins with a series of rather faint lines, but stronger lines appear in the more refrangible part, and the components can be traced to the head of the next group. The green fluting beginning at 5211 also has its strongest lines a considerable distance from the first head, and becomes very faint as it approaches the blue band. Still greater complexity is shown by the blue group of flutings, which has its greatest intensity in the region about 4780, and can be followed to the violet head at 4371. The spectrum, in fact, shows an almost unbroken succession of lines at very short intervals throughout the entire visible spectrum, but the lines are mostly faint, except in the definite flutings to which reference has been made.

The ultra-violet spectrum, of which no measurements have yet been undertaken, also exhibits a great number of lines distributed throughout its whole extent. There is a well-marked fluting, very similar to the one in the green, with its head about 2430, and fading off on the more refrangible side. There is also an interesting series of double lines in the region about 2940 to 3100, in which the lines close up towards the side of shorter wave-length, whereas the somewhat similar series which can be traced in the green and yellow-green flutings converge towards the red.

Another feature of the spectrum, which cannot be very clearly seen in the reproductions, is possibly of some importance. On photographs which have received sufficient exposure, there are patches of unresolved continuous background, sometimes terminated by strong lines, but often by lines which are very faint and indistinct. Intervening places in the spectrum, varying in width from about 0·3 tenth-metre upwards, remain conspicuously clear in the negatives, and have the appearance of bright lines or narrow bright bands.

Similar patches of "dark ground" have been noted by KAYSER and RUNGE in their account of the 3883 fluting of cyanogen,* and the same appearance may be seen in the flutings of titanium oxide and other substances. This appearance, however, does not seem to be special to fluted spectra, as regions of dark ground and exceptionally clear spaces are also found in negatives of the crowded ultra-violet arc spectrum of iron. In the latter case, the darker places are probably due to groups of closely adjacent faint lines, or to an underlying banded spectrum, and the darker places in fluted spectra may similarly be due to groups of faint lines. Attempts to indicate the positions of the dark and bright places in the magnesium hydride spectrum were abandoned, on account of the difficulty of dealing with differences depending upon the dispersion employed and upon differences of exposure.

Determination of Wave-lengths.

The catalogue of wave-lengths which appears at the end of the present paper has been based entirely upon photographs with iron arc comparisons, taken with the concave grating of 10 feet radius. The new standard wave-lengths determined by FABRY and BUISSON† were adopted for the iron lines, and as many as possible of these lines were included in each section of the spectrum measured, so as to furnish a check on the general accuracy of the work. In order to eliminate local systematic errors as far as possible, each of the three flutings to which the catalogue refers was at least once completely measured with the same setting of the plate.

* 'Abh. K. Preuss. Akad. Wiss.,' Berlin, 1889.

† 'Astrophys. Jour.,' vol. 28, p. 195 (1908).

As the spectra were not normal, interpolations were made by equations of the form

$$\lambda = a + bs + cs^2,$$

where λ and s refer to corresponding wave-lengths and micrometer-scale readings, and a, b, c are constants calculated from three of the standard lines. All the standard lines might be made to contribute to the adopted values of a, b, c by the laborious method of least squares, but the gain was found to be scarcely appreciable in a case to which it was applied.

The following example, taken from the measurements of a second-order photograph of the green fluting, will show the accuracy with which the dispersion of the grating over a moderate range may be represented by the above equation. It will also indicate the increased precision which is made possible by the new interference wave-lengths for the iron arc lines as compared with the use of ROWLAND'S values for the absorption lines of iron which occur in the Fraunhofer spectrum.

Equation for FABRY and BUISSON scale :—

$$\lambda = 5260{\cdot}520 - 2{\cdot}67595s + 0{\cdot}000136s^2.$$

Equation for ROWLAND'S scale :—

$$\lambda = 5260{\cdot}678 - 2{\cdot}67544s + 0{\cdot}000132s^2.$$

s in mm.	λ (F. and B.).	O – C.	λ (R).	O – C.	
10·305	5232·958*	000	5233·122*	000	
25·502	5192·362	– 004	5192·523	– 012	
34·827	5167·492	+ 002	5167·678	+ 017	
56·257	5110·415	+ 005	5110·574	– 010	* Used in calculation of constants.
66·435	5083·343*	000	5083·518*	000	
79·055	5049·827	+ 004	5050·008	+ 012	
93·287	5012·072	– 001	5012·252	+ 009	
97·132	5001·880	– 003	5002·044	– 008	
110·645	4966·104*	000	4966·270*	000	

An alternative method of reduction was employed in duplicating the work for the detection of numerical errors. In this case, the two extreme iron lines in each section of the spectrum were employed as standards for the calculation of linear equations, and from the values of O – C for the intermediate standards, curves of error were drawn, from which the corrections to normal were readily derived. Numerous additional checks were also made by simple linear interpolations between iron standards not more than 40 tenth-metres apart.

In spite of every precaution, some of the grating photographs showed small displacements of the magnesium spectrum with reference to the iron comparison, probably arising from the effects of varying temperature during the longer exposures.

The magnitudes of these displacements were determined by reference to the ordinary lines of magnesium, and partly by comparison with wave-lengths derived from photographs of magnesium hydride taken with one pole of iron, and presumably showing no relative displacement.

The stronger lines of the green fluting were measured on second-order photographs, and where the results from different plates were in sufficient accordance, the wave-lengths in the catalogue have been stated to seven figures. It is not claimed, however, that the third decimal is entitled to any great weight, but it has in some cases been found desirable to retain it in the discussion of series lines.

The lines composing the blue group are, on the whole, much fainter than those of the one in the green, so that, although the stronger lines were measured on second-order plates, the accuracy is probably less than that for the green fluting, and the resulting wave-lengths are stated to six figures only. The fainter lines of the blue and green flutings, and the whole of the yellow-green, were determined from photographs of the first-order spectrum, but it is hoped that the errors will rarely exceed 0·02 or 0·03 tenth-metre, except possibly in the case of doubles which are barely resolved.

Retention of ROWLAND'S *Scale.*

As the immediate use of the magnesium hydride wave-lengths is for comparison with the sun-spot spectrum, it has been thought desirable to convert them from the scale of FABRY and BUISSON, on which they were computed, to that of ROWLAND. A very complete investigation of the relation between the two scales has been made by HARTMANN,* who has advocated the general adoption of a slightly modified Rowland scale, which would have the advantage of demanding only small changes in the existing tables of wave-lengths. After due consideration, however, it has been thought that immediate needs would be best met by expressing the magnesium hydride wave-lengths as nearly as possible on the Rowland scale now in use; that is, the scale of the "Preliminary Table of Solar Spectrum Wave-lengths." Comparison of ROWLAND'S solar wave-lengths with the new standards shows that this may be accomplished by adding 0·170 tenth-metre to the values on the Fabry and Buisson scale from 4370 to 5365, and 0·218 tenth-metre from 5365 to the head of the yellow-green band at 5621. The tabulated wave-lengths (in the catalogue at the end of this paper) have accordingly been expressed on this system, and may, therefore, be directly compared with ROWLAND'S solar wave-lengths without introducing errors of inconvenient magnitude. At the same time the wave-lengths stated in this way retain some of the advantages resulting from the use of the new standards, and are directly available for investigations of the series relationships of the different lines, provided that 0·05 be subtracted from the tabulated wave-lengths on the less refrangible side of 5365 when connecting lines on the two sides of this position.

* 'Astrophys. Jour.,' vol. 18, p. 167 (1903); 'Physikalische Zeitschrift,' 10. Jahrg., No. 4, p. 121 (1909).

Moreover, the wave-lengths may readily be reconverted to the Fabry and Buisson scale if so desired.

The Intensity Scale.

The intensities of the various lines have been roughly estimated on a scale of 10 for the strongest lines, ranging down to 1 for the fainter of the well-marked lines. For the faintest lines 0, 00, and 000 have been employed, in accordance with the convenient system adopted by ROWLAND; these are only visible on the plates which have received comparatively long exposures, and 000 is at the limit of visibility. Many of the lines are probably composite, so that a line of stated intensity may sometimes be made up of two or more lines of lower intensity.

Series Lines in the Green Fluting.

A preliminary analysis of the wave-lengths has been made for the purpose of establishing series relationships between the lines of magnesium hydride, and thus obtaining a general check on the accuracy of the wave-length determinations. Some of the related lines were readily picked out by inspection, especially those proceeding from the first heads of the green and yellow-green flutings. Others were identified by their occurrence in pairs, and by the approximate constancy of the second differences between the wave-lengths of successive lines of the series.

The more striking of the probable series occurring in the green fluting are indicated in the general wave-length table by the use of the letters α, β, &c., to mark the associated lines. They are also shown graphically in Plate 12B. The yellow-green fluting exhibits similar series, but the "stride" is considerably larger than in the series composing the fluting in the green. The blue group of flutings is extremely complicated, and no attempt has yet been made to resolve it into its component series.

Many lines which were measured and tabulated as single lines appear to belong to two or more of the series, and it is, therefore, probable that such lines are very close doublets or triplets which could not be separated with the resolving power of the instrument employed. The same conclusion is also indicated by the greater intensities of these lines as compared with adjacent members of the component series. On account of this composite character of many of the lines, and partly for the lack of an exact formula to connect the lines belonging to a given series, the series inquiry does not furnish a complete test of the accuracy of the measurements. Nevertheless, there is sufficient evidence to indicate that the values tabulated cannot be greatly in error.

The general structure of a series will be gathered from the following table, showing the first and second differences between the wave-lengths of the lines composing the α series:—

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

λ.	First differences.	Second differences.	
5211·115			
	0·226		
10·889		258	
	0·484		
10·405†		166	
	0·650		
09·755		240	
	0·890		
08·865		214	
	1·104		
07·761		215	
	1·319		
06·442		218	
	1·537		
04·905		209	† Probably a compound line.
	1·746		
03·159		221	
	1·967		
5201·192		216	
	2·183		
5199·009		198	
	2·381		
96·628		209	
	2·590		
94·038		202	
	2·792		
91·246		226	
	3·018		
88·228		216	
	3·234		
5184·994			

It will be seen that, apart from the influence of a probably compound line, the second differences are sensibly constant throughout the range of visibility of this short series. In the case of the longer series the second differences diminish in passing from the heads, and they are apt to be less regular in the more refrangible parts of the flutings because of the greater overlapping of different systems and the consequent uncertainty as to the wave-lengths of the components of the unresolved lines.

Some of the formulæ which have been suggested for the mathematical representation of series have been tested on series identified in the green fluting. In place of the oscillation frequencies which should strictly have been employed, all the calculations have been made in terms of wave-lengths. In short series the possible error introduced in this way is inappreciable, and some of the equations used are of the same form whether frequencies or wave-lengths are used.

DESLANDRES' simple formula

$$\lambda_m = a - bm^2,$$

where λ is the wave-length, a and b are constants, and m has integer values, is quite inadequate for the magnesium hydride series.

The modification employed by HIGGS,* or its equivalent

$$\lambda_m = a - b(m+\mu)^2,$$

where μ is an additional constant, usually gives only small errors when applied to about a dozen lines, and may, therefore, be employed for the shorter series. By expanding this equation, it assumes the form used by LESTER† for the oxygen bands of the solar spectrum, namely,

$$\lambda_m = a - bm - cm^2.$$

This is somewhat more convenient for purposes of calculation, and the following examples will indicate the accuracy with which it represents the four short series proceeding from the head of the green fluting. The magnitudes of O−C (observed *minus* computed values) are expressed in thousandths of a tenth-metre.

$$\alpha \text{ series}: \lambda_m = 5211{\cdot}115 - 0{\cdot}141m - 0{\cdot}1067m^2,$$
$$\beta \quad ,, \quad \lambda_m = 5210{\cdot}405 - 0{\cdot}3673m - 0{\cdot}10603m^2,$$
$$\gamma \quad ,, \quad \lambda_m = 5210{\cdot}582 - 0{\cdot}5435m - 0{\cdot}10094m^2,$$
$$\delta \quad ,, \quad \lambda_m = 5209{\cdot}940 - 0{\cdot}4891m - 0{\cdot}11317m^2.$$

m.	O − C.				
	α.	β.	γ.	δ.	
0	0*	0*†	0*	0*†	
1	+22	+ 8†	+ 2†	+14	
2	− 1†	+34	−18	−14	
3	+23	+33	+ 2	−10	
4	+21	+33	0*	− 8	
5	+18	+28	−13	0*	* Employed in determinations of constants in equations.
6	+14	+20	−20	− 9	
7	+ 5	0*	− 8	− 1	
8	+ 1*	+ 6	0*	+11	† Probably compound lines.
9	−11	− 1	+57	0*	
10	−26	+ 1	+155		
11	−25	+13			
12	−20	+ 7			
13	− 4	+19			
14	0	− 1*			
15	+ 1*				

Apart from the probably composite lines, the differences between the observed wave-lengths and those calculated from the formulæ, although small, are largely systematic and are apparently due chiefly to the impossibility of accurately repre-

* 'Roy. Soc. Proc.,' vol. 54, p. 200 (1893).

† 'Astrophys. Jour.,' vol. 20, p. 81 (1904).

senting the series by equations of so simple a type. The equation is especially unsuited to the γ series, assuming that the last lines have been correctly assigned; the second differences in this case vary rapidly towards the end, and only the first nine lines are reasonably represented by the equation.

The long series marked ϵ and ζ, which comprise many of the stronger lines of the green fluting, provide a better test of formulæ which have been proposed, and it may be of interest to refer to some of the results obtained for the ϵ series, which includes about forty lines extending over a region of about 160 tenth-metres.

When calculated for the first thirteen lines of the ϵ series, LESTER'S equation gives no error as great as 0·01 tenth-metre, but if eight additional lines are included, and the two extreme lines are used in the calculation of constants, the maximum errors exceed 0·1 tenth-metre, and the formula is clearly inapplicable to the whole series. Better results have been obtained by including another term in the equation, but an appreciable systematic error remains even if only lines between the first and twenty-second are employed in the determination of constants. If applied to the whole series, this extended form of LESTER'S equation gives systematic errors which reach a maximum of 0·15 tenth-metre.

Another equation which has been tested on the ϵ series is that deduced by HALM* from one adapted to line series, namely,

$$\frac{1}{\lambda_0-\lambda_m}=\frac{\alpha}{(m+\mu)^2}+\beta,$$

where the constants λ_0, α, β and μ are calculated from four of the lines. This represents the first twenty-one lines with an accuracy nearly equal to that of the measurements, but considerable systematic errors remain when it is applied to the whole series. The true equation connecting the lines of a fluting series, therefore, remains to be discovered, and until some progress has been made in this direction, and still greater dispersion can be effectively employed, it does not seem worth while to pursue the matter further.

The numerical results of the calculations for the ϵ series, however, may be useful to those interested in this inquiry, and they are accordingly brought together in the appended table. Numbers below the horizontal lines are results of extrapolation.

Comparison with the Sun-spot Spectrum.

It is interesting to recall that the possible local occurrence of magnesium hydride in the sun was clearly recognised by LIVEING and DEWAR in their paper of 1880.† Referring to the head of the green fluting at 5210, they wrote: "A line of the same wave-length has been seen by YOUNG in the chromosphere once. Its absence from the Fraunhofer lines leads to the inference that the temperature of the sun is too high

* 'Trans. Roy. Soc. Edin.,' vol. 41, p. 551 (1905).

† 'Roy. Soc. Proc.,' vol. 30, p. 97 (1880).

Calculations of ϵ Series.

Lester's formula

$$\lambda_m = 5183\cdot364 - 1\cdot118m - 0\cdot08879m^2 \quad \ldots \quad (1)$$

$$\lambda_m = 5183\cdot364 - 1\cdot14475m - 0\cdot08617m^2 \quad \ldots \quad (2)$$

$$\lambda_m = 5183\cdot364 - 1\cdot0941m - 0\cdot094296m^2 + 0\cdot0002808m^3 \quad \ldots \quad (3)$$

$$\lambda_m = 5183\cdot364 - 1\cdot03835m - 0\cdot1011146m^2 + 0\cdot00047434m^3 \quad \ldots \quad (4).$$

Halm's formula

$$\frac{1}{5186\cdot642 - \lambda_m} = \frac{10\cdot7384}{(m+5\cdot938)^2} + 0\cdot00053 \quad \ldots \quad (5)$$

$$\frac{1}{5186\cdot428 - \lambda_m} = \frac{10\cdot45245}{(m+5\cdot665)^2} + 0\cdot0006743 \quad \ldots \quad (6).$$

λ.	m.	O − C (in thousandths of 1 tenth-metre). 1.	2.	3.	4.	5.	6.
5183·364	0	0*	0*	0*	0*	0*	0*
82·149	1	− 8	+ 16	− 27	− 76	− 21	− 41
80·764	2	− 9	+ 34	− 37	− 123	− 28	− 64
79·207	3	− 4	+ 53	− 34	− 145	− 25	− 72
77·476	4	+ 4	+ 69	− 21	− 147	− 13	− 69
75·556	5	+ 2	+ 70	− 15	− 148	− 10	− 69
73·460	6	0*	+ 66	− 4	− 136	− 3	− 63
71·181†	7	− 6	+ 53	0*	− 123	0*	− 58
68·734	8	− 4	+ 43	+ 14	− 95	+ 11	− 41
66·104	9	− 6	+ 22	+ 21	− 70	+ 16	− 30
63·300	10	− 5	0*	+ 26	− 43	+ 20	− 17
60·324	11	+ 3	− 21	+ 31	− 15	+ 26	− 2
57·163	12	+ 1*	− 55	+ 21	0*	+ 17	0*
53·826	13	+ 2	− 94	+ 4	+ 7	+ 2	− 4
50·335†§	14	+ 26	− 113	0*	+ 25	0*	+ 4
46·689	15	+ 73	− 116	+ 6	+ 50	+ 8	+ 21
42·868	16	+ 122	− 121	− 1	+ 60	+ 4	+ 26
38·885†	17		− 115	− 7	+ 65	0	+ 27
34·755†	18		− 84	− 1	+ 76	+ 7	+ 38
30·436†	19		− 71	− 25	+ 49	− 17	+ 13
26·003	20		+ 2*	− 8	+ 57	− 1	+ 24
21·404	21		+ 81	0*	+ 44	+ 1*	+ 17
16·636†	22		+ 163	− 9	+ 4	− 17	− 15
11·793	23			+ 60	+ 29	+ 38	+ 19
06·759	24			+ 86	0*	+ 47	0*
5101·590†	25			+ 126	− 30	+ 62	− 20
5096·335	26				− 16		+ 6
90·907	27				− 46		− 14
85·365	28				− 65		− 23
79·700	29				− 83		− 34
73·940	30				− 78		− 23
68·066	31				− 69		− 13
62·060	32				− 79		− 24
56·000	33				− 31		+ 18
49·810†	34				− 5		+ 33
43·500	35				+ 6		+ 28
37·070	36				0*		0*
30·61	37				+ 64		+ 31
5024·03	38				+ 104		+ 33

* Lines used in calculation of constants.

† Probably compound lines, belonging to more than one series.

§ Adopted as ϵ component of compound line for purposes of calculation, in place of wave-length in general table.

(*unless at special times and places*)* for its production. If it be not due to a compound of magnesium with hydrogen, at any rate it occurs with special facility in the presence of hydrogen, and ought to occur in the sun if the temperature were not too high."

There is no evidence of the presence of the fluting as a whole in the chromospheric spectrum, and as the first head line at 5211·11 does not agree accurately with either of YOUNG's lines near its position, it must be concluded that magnesium hydride does not appreciably contribute to the spectrum of the chromosphere. In the sun-spot spectrum, however, the green fluting of magnesium hydride is strongly marked, and at least the stronger components of the yellow-green and blue flutings are also easily traced in the Mount Wilson and Kodaikanal photographs. In the spot spectrum the lines are somewhat hazy, and belong to the class called "band lines" or "umbra lines"; in the regions where they occur they appear to be the more conspicuous of the multitude of lines into which the dark background of the spot spectrum is resolved when high dispersion is employed.†

Complete series of measurements of the band lines of the spot spectrum are not yet available. A few of them have been noted from visual observations by MAUNDER, MITCHELL, and myself, and 127 were tabulated between 5212 and 5032 by HALE and ADAMS from the earlier photographs of the spot spectrum‡ taken at Mount Wilson. Even the latter catalogue, however, is far from complete, although it contributed largely to the first identification of magnesium hydride in the spot spectrum. Under these circumstances, an exhaustive comparison of the two spectra cannot yet be given, and indeed such a comparison is more appropriate to a detailed discussion of the sun-spot spectrum than to the present paper.

A convincing demonstration of the presence of magnesium hydride in spots, however, is afforded by the photographs reproduced in Plate 13, showing the spectra in the region 5212–5062. The photographs of the sun and sun-spot spectra were taken by Mr. EVERSHED at the Solar Observatory, Kodaikanal, India, and were kindly placed at my disposal by the Director, Mr. C. MICHIE SMITH; the exposure given to the sun-spot was about six times as long as that for the sun. The magnesium hydride photograph was taken in the second order of the 10-feet concave grating, and is presented as a negative in order to represent an absorption spectrum. It will be seen that, apart from the interference caused by metallic lines, all the details of magnesium hydride are reproduced in the spot spectrum.§

Effective comparisons of the spot with the yellow-green and blue flutings cannot

* The italics are mine.—A. F.

† YOUNG, 'Amer. Jour. of Sci.,' 3rd series, vol. 26, p. 333 (1883). A useful summary of subsequent observations is given by HALE and ADAMS in 'Astrophys. Jour.,' vol. 23, p. 30 (1906).

‡ 'Astrophys. Jour.,' vol. 23, p. 36 (1906).

§ Lines at 5169·96 and 5169·42 in the photograph of magnesium hydride, which do not appear in the spot spectrum, are "ghosts" of b_1 and b_2. Certain other lines in this photograph, as 5197·57 and 5187·26, are relatively too strong in consequence of ghosts which are nearly coincident with them.

yet be given, but there is sufficient evidence that many of the band lines in these regions are certainly due to magnesium hydride.

To determine exactly the amount of detail in the spot which is accounted for by magnesium hydride will necessarily involve a comparison of wave-length measurements. In this investigation, identity of numerical values must not in every case be expected, in consequence of the presence of so many other lines in the spot spectrum. Thus, the line 5186·59 is evidently combined in the spot with a titanium line at 5186·50, giving rise to an apparent discordance with the wave-length 5186·53 assigned to the spot line by HALE and ADAMS. Such combinations will likewise produce apparent small displacements of the metallic lines. It should be noted also that the apparent intensification of some of the metallic lines, as for example the faint iron line 5177·41, must be due, in part at least, to superposed lines of magnesium hydride, and similarly that in some cases the weakening of metallic lines may be obscured. Further, some of the magnesium hydride lines appear as mere fringes to comparatively strong metallic lines, and are likely to be overlooked if not specially sought. These are some of the points that must be taken into consideration when a minute comparison with the spot spectrum is undertaken.

There is another feature of the spot spectrum which is to some extent explained by the identification of magnesium hydride, namely, the bright interruptions which occur in the dark background of the spot spectrum. YOUNG observed that these inter-spaces, some of which are quite narrow and look like bright lines, were of the same order of brightness as the undimmed spectrum outside the spots, and the observation has been repeatedly confirmed by others. The account given by HALE, ADAMS, and GALE,* from observations made in the 3rd and 4th orders of a Littrow grating spectroscope of 18 feet focal length, may be usefully quoted: "Although an immense number of fine lines can be seen in the spot spectrum, they nevertheless seem to lie on a continuous dark background, which we have not been able to resolve into lines. This background, however, is interrupted at certain points by lines or breaks, which seem to be nearly as bright as the spectrum of the adjacent photosphere. They do not appear to us like genuine bright lines, and we are unable to offer an adequate explanation of them, unless the dark background is resolvable."

As no wave-lengths were given by the Mount Wilson observers, it is not quite certain that the bright interruptions which they observed are identical with those seen in the Kodaikanal photograph of the spot spectrum shown in Plate 13, where the resolving power is not so great. The latter, however, represents very closely the appearance and positions of the bright spaces as observed with the Evershed solar spectroscope employed in my own observations of spots, which gives a purity of about 25,000 near b, and a dispersion of 60° from A to H. The great majority of these, in the region about b, are coincident with clear spaces in the absorption of magnesium hydride (see p. 454), except, of course, that the latter are sometimes sub-divided,

* 'Astrophys. Jour.,' vol. 24, p. 185 (1906).

narrowed, or nearly obliterated in the spot spectrum by superposed metallic lines. In the case of magnesium hydride, the gaps are not well displayed as such in the photograph reproduced in Plate 13, but they form a prominent feature in the photograph of the green fluting on Plate 12A, No. 3, which was given a relatively much longer exposure. Among the many gaps common to the two spectra are 5180·9, 5179·4, 5177·2, and 5176·6. It follows, then, that such bright places in the spot spectrum cannot be bright lines superposed on a truly continuous dark background, but simply represent wave-lengths for which magnesium hydride is most transparent. Further investigation is necessary to determine whether the possibly narrower gaps seen with the most powerful instruments are explained in the same manner.

It may be remarked that magnesium hydride is not the only probable compound which is represented in the spot spectrum. HALE and ADAMS* have shown that the flutings which I identified in the Third-type stars and have attributed to titanium oxide† are a very prominent feature in the red region, and two additional flutings at 6382 and 6389 have been traced to calcium hydride (or, at least, to calcium in the presence of hydrogen) by OLMSTED at the Mount Wilson laboratory.‡ The discovery of these fluted spectra favours the view that spots are regions of local cooling, which was previously suggested by the behaviour of different classes of metallic lines.§

It is probable also that the combined absorption of the thousands of lines belonging to these spectra, extending as they do from the extreme red to the far ultra-violet, contributes materially to the darkness of sun-spots, and absorption corresponding to the "dark ground" occurring in negatives of these spectra will doubtless aid the process of darkening. It cannot be concluded, however, that the absorption of the substances now known to be present in spots is adequate to account entirely for the darkening, as the spot spectrum is darker than the photospheric spectrum in places where the known band spectra are feeble, as, for example, to the red side of the green fluting of magnesium hydride at 5211, and in the ultra-violet region.

A further contribution to the darkness might be made by the scattering of the photospheric light in its passage through the vapours of the spot, or by reduced emission from the underlying photosphere. These, however, would seem to be inadmissible if the bright interruptions of the spot spectrum be really as bright as the corresponding places in the ordinary photospheric spectrum. In visual observations the interruptions certainly appear to be of the same order of brightness as the adjacent photospheric spectrum, but it is difficult to allow for contrast effects, and I am glad to learn that this point is under investigation by photographic methods at Kodaikanal.

* 'Astrophys. Jour.,' vol. 25, p. 76 (1907).

† 'Roy. Soc. Proc.,' vol. 73, p. 219 (1904); vol. 79, p. 509 (1907). 'Monthly Notices, R.A.S.,' vol. 69, p. 508.

‡ 'Astrophys. Jour.,' vol. 27, p. 66 (1908).

§ FOWLER, 'Trans. Internl. Union Sol. Res.,' vol. 1, p. 228 (1906); HALE, ADAMS, and GALE, 'Astrophys. Jour.,' vol. 24, p. 185 (1906).

Possible Indications of Magnesium Hydride in the Normal Solar Spectrum.

According to the observations of YOUNG* and DUNÉR,† the "band lines" of the sun-spot spectrum, many of which have now been shown to be due to magnesium hydride, would appear to be present as very faint lines in the normal solar spectrum. The same conclusion was also suggested by my own observations,‡ which showed that bright interspaces in the spot spectrum sometimes occupied spaces between nebulous lines of low intensity tabulated by ROWLAND, the lines themselves not being seen with the dispersion available.

From observations made with the very powerful instruments at Princeton, however, W. M. MITCHELL was led to express doubts as to whether the greater part of the band lines are ordinarily exceedingly faint lines in the photospheric spectrum which are brought into prominence by the vapours in the spot, and was inclined to the opinion that the band lines are not present in the photospheric spectrum at all.§ In opposition to this, HALE and ADAMS|| found, from measurements of their large-scale photographs of the spot spectrum, that the wave-lengths of the band lines agreed very closely with the wave-lengths of very faint lines in ROWLAND'S tables, and they regarded this as a proof that the substance producing the band lines contributes feebly to the ordinary solar spectrum.

Nevertheless, a critical examination of the table given by HALE and ADAMS, taking account of our present knowledge of the magnesium hydride spectrum, suggests that many of the supposed coincidences are purely accidental. The strongest lines of magnesium hydride, if present at all in the Fraunhofer spectrum, are only represented by lines of intensity 000 or 0000 in ROWLAND'S tables, and it is accordingly very improbable that the fainter lines would reveal their presence in any photographs of the solar spectrum now available. Yet some of these faint magnesium hydride lines appear to be identical with band lines then supposed by HALE and ADAMS to correspond with solar lines.

The chief difficulty in arriving at a satisfactory conclusion on this point arises from the fact that there are so many lines in the magnesium hydride spectrum and in the solar spectrum that numerous chance coincidences might be expected even if there were no real relation between the two. The application of the theory of probabilities is somewhat uncertain, and an attempt has therefore been made to obtain further light on the subject by comparing the relative numbers of coincidences of strong and faint lines of magnesium hydride with the solar lines. To allow for possible errors in the two sets of measurements, and for the fact that ROWLAND'S standards have not

* 'Amer. Jour. of Sci.,' 3rd series, vol. 26, p. 333 (1883).

† 'Recherches sur la Rotation du Soleil' (Upsala, 1891).

‡ 'Monthly Notices,' R.A.S., vol. 65, p. 516 (1905).

§ 'Astrophys. Jour.,' vol. 22, p. 4 (1905).

|| 'Astrophys. Jour.,' vol. 23, p. 34 (1906).

been employed in the case of the laboratory spectrum, lines have been considered coincident when they agreed within 0·033 of a tenth-metre. It will suffice to summarise the results of this comparison, which covers the region 5180·7 to 5090·2.

In this region there are 55 lines of intensity 5 and upwards in the magnesium hydride spectrum; 31 of these, or 56 per cent., agree within the specified limit with solar lines; 19, or about 35 per cent., do not agree within this limit; and 5 are certainly or possibly masked by metallic lines.

In the same region there are also 55 magnesium hydride lines of intensity 0 and less, solar coincidences with which must be regarded as accidental. Of these, 22, or 40 per cent., agree with solar lines within the limit stated; 31, or 56 per cent., do not agree; and 2 are probably confused with metallic lines.

The difference in the representation of the two groups of lines is perhaps sufficient to indicate that the stronger lines of magnesium hydride may be really present as very faint lines in the Fraunhofer spectrum, but the evidence is less convincing than might be desired, especially as some of the strongest magnesium hydride lines do not appear in ROWLAND's catalogue. There is, however, some doubt as to the completeness of ROWLAND's record of the very faint lines,* and until this is removed no final conclusion can be reached.

Another attempt to obtain evidence upon this point has been based upon the series lines to which reference has already been made. ROWLAND's relative wave-lengths might be expected to be sufficiently accurate to show nearly constant second differences for lines corresponding to a given series, if the supposed solar coincidences were really significant, but this test cannot be very effectively applied in consequence of the frequent interruption of the possible series by superposed metallic lines. In the case of the ζ series, however, there are five consecutive lines which are free from this complication, details of which are given in the appended table:—

Magnesium hydride.			Sun.		
λ and intensity.	First differences.	Second differences.	λ and intensity.	First differences.	Second differences.
5170·766 (8)			5170·767 (000)		
	2·438			2·407	
68·328 (8)		·174	68·360 (000Nd?)		·207
	2·612			2·614	
65·716 (8)		·184	65·746 (0000)		·230
	2·796			2·844	
62·920 (8)		·180	62·902 (0000)		·112
	2·976			2·956	
59·944 (8)			59·946 (0000)		

* JEWELL, 'Trans. Internl. Union Sol. Res.,' vol. 1, pp. 49, 50.

It will be seen that the solar wave-lengths do not show such uniform second differences as are given by the magnesium hydride lines. Various small corrections might be made to bring them into better accordance with the series law, but at least one of them must be of the order of 0·025 tenth-metre, which seems to be too great an error to be attributed to ROWLAND's relative wave-lengths in so small a region of the spectrum. The series evidence, so far as it goes, is accordingly somewhat against the identification of solar lines with magnesium hydride.

As a result of the whole investigation, it is only possible at present to say that a very small percentage, if any, of the faint lines of the normal solar spectrum are likely to be accounted for by magnesium hydride.

Summary.

(1) No sufficient reason has been found for modifying LIVEING and DEWAR's conclusion that the spectrum under investigation is produced by the combination of magnesium with hydrogen, and the spectrum has accordingly been referred to throughout as that of magnesium hydride.

(2) The magnesium hydride spectrum exhibits lines at very short intervals from the extreme red to λ 2300, and shows definite groups of flutings having their first head lines in the yellow-green at 5621·57, in the green at 5211·11, in the blue at 4844·92, in the violet at 4371·8, and in the ultra-violet near 2430.

(3) From photographs of the magnesium arc in hydrogen, taken with a concave grating of 10 feet radius, the positions of close upon 2000 lines composing the three principal flutings have been determined. The wave-lengths were derived from the interference standards of FABRY and BUISSON, but have been converted to Rowland's scale to facilitate comparison with solar spectra.

(4) Twelve of the series of lines which compose the green fluting have been traced, and it is shown that none of the formulæ which have been proposed are sufficiently general in their application to represent all of these series within the limits of error of measurement. For the longer series the closest approximation is given by HALM's equation.

(5) The identification of magnesium hydride in the sun-spot spectrum has been fully confirmed, and is clearly demonstrated by photographs which are reproduced.

(6) It is shown that many of the bright interruptions of the dark background of the spot spectrum are not bright lines, but merely clear interspaces between lines or groups of lines in the spectrum of magnesium hydride.

(7) The presence of the magnesium hydride flutings, together with flutings of titanium oxide and calcium hydride discovered at Mount Wilson, accords with the view that spots are regions of reduced temperature, and that their darkness is at least partly due to absorption.

(8) The investigation of the possible presence of lines of magnesium hydride in the

ordinary solar spectrum is for several reasons inconclusive, but there is evidence that very few, if any, of the thousands of faint lines tabulated by ROWLAND are to be accounted for by this substance.

In concluding this paper, I am anxious to express my indebtedness to those who have rendered assistance in a somewhat laborious investigation. Mr. H. SHAW, A.R.C.S., has made many of the calculations for checking my determinations of wave-lengths, and Mr. A. EAGLE, B.Sc., has been especially helpful in the experimental part of the work, which he has carried out with great skill. Valuable assistance was also given by Mr. T. BANFIELD in preparing the photographs for reproduction.

Description of Table of Wave-lengths.

The wave-lengths are expressed as nearly as possible on the scale of ROWLAND'S "Preliminary Table of Solar Spectrum Wave-lengths." They may be reconverted to the "absolute" scale of FABRY and BUISSON, on which they were originally calculated, by *subtracting* 0·22 from 5621 to 5365·1 inclusive, and 0·170 from 5365·1 to 4371.

In the column headed "Int." (intensity), the brightest lines are represented by 10 and the fainter lines by numbers ranging down to 1, while the faintest lines, as in ROWLAND'S tables, are denoted by 0, 00, and 000. The letter "n," following the intensity number, indicates that the line is unusually nebulous or diffuse, while "s" indicates that the line is of more than average sharpness; d? indicates that the line is probably double, though not clearly measurable as such. Some of the lines marked "n" may possibly also be double.

In the table referring to the green band, the letters α, β, &c., indicate the lines which are probably associated in the respective series.

It should be noted that some of the magnesium hydride lines may be masked by the ordinary arc and spark lines of the metal magnesium which appear on the plates from which the wave-lengths were determined, namely: the arc lines 5528·641, 5183·791, 5172·856, 5167·497, 4703·177, 4571·275, and the enhanced line 4481·31.

YELLOW-GREEN FLUTING.

λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.
5621·57	1	5618·69	1	5614·54	0	5604·73	1	5599·17	1n
21·22	1	18·23	00	13·66	1	04·14	1	98·76	0n
20·92	1	17·73	1	13·11	1	03·56	00	98·08	0
20·54	2n	17·16	1	11·04	1	01·70	00	97·31	1n
20·38	0	16·48	0	10·48	1	01·05	1	97·01	1n
19·76	2d?	15·86	1	08·05	1	5600·50	1	96·44	2
5619·23	0	5615·30	1	5607·48	1	5599·90	00	5595·33	1

Yellow-Green Fluting (continued).

λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.
5594·50	1n	5555·81	00	5520·77	1	5491·32	1	5460·95	00
92·89	2	55·29	00	20·39	0	90·53	1	60·34	000
92·59	0	54·34	1	20·32	2	89·34	00	59·41	1n
92·15	2	53·76	1	19·93	0	88·96	1	58·88	0n
92·05	0	53·28	00	18·98	1	88·63	0	58·23	0n
90·74	00	52·24	00	18·59	2	88·55	2	57·98	0
90·14	2	51·86	00	17·82	00	87·93	2	57·58	0
89·53	2	51·32	2	17·17	0	87·55	2	57·22	00
88·83	00	50·92	4	16·64	1	86·99	0n	56·61	1
87·77	1	50·42	00	16·23	2	86·52	0n	56·32	1
87·12	2	49·79	1	15·77	3	86·12	0	56·15	2
86·55	2	49·06	1d?	15·40	00	85·78	1	55·85	0
85·29	0n	48·37	00	14·81	00	85·06	0	55·19	00
83·75	2	47·53	1	14·31	0d?	84·92	0	54·57	1
83·22	2	47·16	0	13·52	00	84·41	0d?	54·36	2
82·61	1	46·67	0n	13·00	0	83·65	1	53·96	1
82·05	1	46·38	0n	12·80	0	83·31	00	53·22	00
81·43	00	45·79	0	12·46	1	82·57	4	52·47	1
80·70	00	45·43	2	12·02	00	82·21	2	52·07	2d?
80·08	2	45·01	2	11·59	3	81·93	0	51·90	0
79·56	2	44·86	0	11·37	2	80·24	0	51·38	00
77·07	0	44·23	0	11·24	2	79·45	2	51·22	2
76·49	00	43·76	2n	10·95	4	79·02	5d?	50·78	1
76·05	2	43·05	0	10·46	00	78·42	0	50·58	0
75·57	2	42·93	1d?	09·70	1	78·06	0	49·74	1
75·35	00	42·58	00	09·14	1	77·53	0	49·27	1
74·54	00	42·22	1	08·35	000	76·74	00	48·67	00
73·73	1	41·45	2n	07·28	0	75·97	1	48·17	1
72·39	00	40·72	1	06·74	1	75·56	1	47·59	4
71·74	2	40·15	0	06·25	2	75·15	3	46·55	1
71·25	3	39·86	000	06·01	00	74·65	1	46·14	1
70·72	1	39·27	1	05·79	3	74·22	00	46·00	0
68·32	2	38·81	4	04·57	00	72·79	00	45·53	1d?
67·70	3	38·65	1	04·20	00	72·06	1	45·08	2
67·13	3	38·12	2	04·03	3	71·50	1	44·94	0
66·90	1	36·57	00	03·64	3	70·97	1	44·00	1n
66·65	2	35·74	3d?	02·70	000	70·68	1	42·98	1
66·38	0	35·16	2	01·99	00	70·36	3	42·59	1
65·72	1n	34·24	000	01·53	00	69·75	0	42·20	0
65·06	1n	33·83	1s	00·78	3	69·00	2	41·74	0
64·43	00	33·28	1	5500·33	4	68·85	2	40·89	0n
64·13	1	32·79	1	5499·66	0	68·64	2	40·45	00
63·61	1	32·44	4	99·28	00	68·35	00	39·97	0
62·76	1	31·95	1	98·81	0	66·51	1	39·50	2n
62·17	4	30·30	00	98·11	000	66·00	1	39·09	5
61·70	3	27·66	00	97·72	0n	65·80	00	38·48	3
61·08	00	26·70	0n	97·40	1n	65·14	0n	38·12	2
60·77	00	26·05	2	97·00	0n	64·87	0n	37·37	000
59·95	1	25·62	2	96·06	1	64·35	2	36·19	0n
59·42	1	25·00	2	95·67	4	64·08	1	35·78	0n
58·48	00	24·49	2	95·15	0	63·75	1	35·30	0n
57·82	00	24·17	1	95·05	1	63·38	1	34·75	00n
57·33	0	23·22	1	94·59	2	62·30	00	34·31	00n
56·89	1	22·73	0	93·65	2	61·74	5d?	33·21	3
56·75	1	21·89	00	92·98	0n	61·39	3 } d?	32·87	4d?
5556·43	3	5521·22	00	5492·70	1	5461·28	3 }	5432·29	00

Yellow-Green Fluting (continued).

λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.
5431·96	0d ?	5401·65	0	5368·96	000	5335·05	0	5297·46	00
31·63	0	01·28	1	67·43	0	34·26	2d ?	96·52	00
31·05	1s	01·12	2	66·85	0	32·86	0	95·27	00
30·54	0	5400·53	0	66·36	00	32·44	00	94·74	0
30·15	1	5399·62	0	65·92	1	31·78	00d ?	93·98	00
29·78	1	98·96	00n	65·65	0	31·25	0	93·34	00
29·39	1	98·54	0	65·29	0	31·04	1	92·97	0n
28·82	0	98·04	1	65·17	0	30·59	00	92·26	0
26·66	2	97·36	3	64·17	1	29·84	2	91·81	000
26·22	1	97·02	1	63·71	2	29·31	1	91·48	2s
25·54	1	95·80	1	63·31	00	28·60	00	91·18	1
24·98	0	95·36	0n	62·92	1	28·37	00	90·06	00n
24·61	0	95·16	00	62·47	0	27·72	00	89·59	00n
24·07	0d ?	94·08	2	61·96	0	25·41	0n	88·54	00n
23·17	1	93·65	3	61·44	00	24·88	00	88·16	0
22·78	1	93·53	0	60·89	0	24·40	0n	86·80	00n
22·15	1	93·05	0	60·37	1n	24·04	1n	86·02	00n
21·55	3	92·62	00	57·95	0	23·62	0	84·96	00n
21·40	3	91·59	1	57·64	00	21·97	0	84·17	0
21·16	1s	91·21	1nd ?	57·36	0	21·33	2	83·70	00
20·90	0s	91·07	00	56·71	0n	20·81	0	83·27	00
20·23	00	90·40	00	55·61	2	20·35	1	82·88	1
19·53	1	89·78	1	55·06	1	19·60	00	82·51	00
19·36	1	89·31	2	54·67	1	18·82	000	81·43	00
19·14	0	88·84	1n	54·27	0	16·51	0n	80·91	1
18·48	00	88·73	00	54·05	1	16·15	0n	80·52	0
17·45	0	87·80	1n	53·72	0	15·62	00	80·05	000
17·28	0	87·28	0	53·48	0	15·03	00	79·85	0
16·85	0d ?	85·58	00	53·18	0	14·11	00	79·35	00
16·42	1	85·05	0	50·65	00	12·79	2	78·68	0n
15·96	00	84·78	1	50·00	0	13·30	1	77·87	00
15·12	0	84·37	2s	49·41	1	12·63	00	77·00	0n
13·46	00	83·96	1	49·00	00	11·38	00	74·41	00
12·97	1	83·42	0	48·50	1	11·01	00	73·40	0
12·57	5d ?	83·00	0	47·78	00	10·70	0	73·00	0
12·19	3	82·36	0	46·79	0	10·13	00n	72·36	0
11·71	00	81·64	0	46·38	2s	09·58	000	71·91	00
11·00	1n	80·99	0	45·66	1n	08·75	1	71·05	1
10·24	0n	80·56	1	44·48	1n	08·50	1	69·71	0
09·95	0n	79·86	00	44·02	2	08·15	00	69·40	1
09·57	1	78·70	00	43·50	1	07·48	0n	68·84	00
09·14	2	78·06	1	42·93	1	06·76	0n	67·84	00
08·66	1	77·65	00	42·70	1	06·18	00	67·43	0
08·05	000	76·72	3	42·30	1	05·50	00	66·93	00
07·45	00	76·31	3	41·20	1s	05·21	00	66·17	000
07·09	1	74·73	0	40·72	000	04·75	00	64·44	000
06·64	00	74·51	0	40·31	00	03·87	00	64·33	0
06·47	1	74·10	3	39·52	0n	02·94	00	62·59	0
05·54	00	73·39	000	39·16	0n	02·48	00	61·87	00
05·17	2	72·27	1	38·43	1n	01·62	0	58·15	0
04·75	1	71·90	0	38·07	0	01·17	00	57·76	0
04·25	0	71·27	1	37·70	1s	00·47	0n	57·01	00n
03·58	3d ?	70·43	1	37·27	00	5300·22	0n	56·65	00n
03·14	2	69·92	1	36·80	00	5299·56	00	55·96	0
02·44	0n	69·81	1	36·34	0n	99·00	0	55·50	00
5401·98	0	5369·25	0	5335·60	00	5298·08	00	5254·79	00

Yellow-Green Fluting (continued).

λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.
5254·29	00	5244·69	00	5233·19	1n	5223·43	1n	5214·86	00
53·84	00	44·00	00	31·54	0	22·66	00	14·31	00
53·11	00	42·08	0n	30·35	0	21·23	000	13·74	0
52·86	0	41·62	00	29·59	0	19·51	0n	13·20	000
52·40	00	41·08	00	28·41	0	18·82	00	12·98	1
50·60	1s	40·35	0	27·34	00	18·33	1	5212·75	00
49·67	1n	39·65	0	26·82	0s	17·30	000		
47·64	00n	37·63	0n	26·17	00s	16·74	000		
46·54	00	36·04	00n	25·62	00	16·29	00		
5246·00	1s	5235·07	00	5224·77	000	5215·85	0n		

Green Fluting.

λ.	Int.	Series.	λ.	Int.	Series.	λ.	Int.	Series.	λ.	Int.	Series.
5211·115	5	α	5199·774	4	γ	5182·149	4	ε	5172·312	0	
10·889	5	α	99·009	3	α	81·909	2		72·079	2	
10·582	5	γ	98·795	1	δ	81·687	2		71·715	1	
10·405	7	αβ	98·510	3	β	81·430	3	ζ	71·181	9	ε
09·940	6	βγδ	97·571	4†	γ	81·360	3†		70·766	8†	ζ
09·755	4	α	96·628	3	α	81·062	1		70·269	1n	
09·352	3	δ	96·371	0	δ	80·764	7	ε	69·635	1n	
09·280	3	β	96·130	3	β	80·540	1†		68·734	8	ε
09·073	2	γ	95·208	3	γ	80·162	7	ζ	68·328	8	ζ
08·865	3	α	94·038	3	α	79·937	00		68·011	1	
08·495	3	δ	93·548	3	β	79·718	0n		67·22	1	
08·382	3	β	92·771	2	γ ?	79·577	0n		66·104	8	ε
08·045	3	γ	92·04	00n		79·207	7	ε	65·716	8	ζ
07·761	3	α	91·246	3	α	78·920	0		65·39	00	
07·444	3	δ	90·736	3	β	78·653	7	ζ	65·08	0	
07·272	3	β	90·403	1	γ ?	78·364	0		63·792	3	
06·793	3	γ	89·51	0n		78·221	0		63·300	8	ε
06·442	3	α	89·17	00n		78·00	00		62·920	8	ζ
06·165	2	δ	88·228	3	α	77·762	1		62·01	00	
05·946	3	β	87·730	2	β	77·476	8	ε	61·65	0	
05·328	4	γ	87·258	3†		76·975	8	ζ	61·20	0	
04·905	3	α	86·587	3†		76·298	3†		60·324	8	ε
04·665	2	δ	85·914	4		75·98	1 } d ?		59·944	8	ζ
04·404	3	β	85·582	00		75·91	1 }		59·431	3	
03·667	3	γ	85·196	5	ε ?	75·556	8	ε	58·781	3	
03·159	3	α	84·994	2	α	75·371	00		58·485	1	
02·922	2	δ	84·480	1	β	75·087	8	ζ	57·751	3	
02·638	3	β	84·325	5	ε ?	74·817	1		57·163	8	ε
01·823	4	γ	83·364	4	ε	74·617	2		56·806	8	ζ
01·192	3	α	82·948	00		74·166	1		56·492	1	
00·970	1	δ	82·532	3	ζ	73·460	8	ε	56·22	00	
5200·687	3	β	5182·463	3		51(73·020)	(8)*	ζ	5155·910	4	

* Masked by the magnesium line b_2, but interpolated from series relation.

† The intensities of these lines are slightly increased by "ghosts" of the b lines.

Green Fluting (continued).

λ.	Int.	Series.	λ.	Int.	Series.	λ.	Int.	Series.	λ.	Int.	Series.
5155·60	0		5134·390	5	ζ	5116·162	2		5093·759	2	σ
55·319	2		33·747	3	κ	15·204	1		92·750	3	
55·048	2		33·353	4	μ	14·740	3	ρ	92·310	3	
54·879	4n	κ	33·018	2	ρ	14·208	4	σ	91·840	3	κ
54·684	1		32·69	00		13·747	1		91·479	3	μ
54·365	3		32·330	2	σ	13·317	4	η	90·907	4	ε
54·284	3		32·007	1		13·140	2	κ	90·549	4	ζ
54·009	2	μ	31·82	0		12·832	5	μθ	90·21	00	
53·826	7†	ε	31·385	1		12·330	1		89·98	0	
53·470	7	ζκ	31·136	1		11·793	5	ε	89·66	00	
53·14	00		30·707	3	κ	11·462	5	ζ	89·383	4	η
52·786	3	μ	30·436	6	ε	11·176	2		88·894	5	θ
52·37	0		30·323	2	μ	09·803	2	ρ	88·80	3	ρ
52·043	2		30·073	5	ζη	09·228	4d?	κσ	88·33	1	σ
51·964	2	κ	29·992	1		08·830	4	μ	87·97	0n	
51·62	00		29·68	00		08·433	2		87·41	00	
51·355	3	μ	29·495	4	θ	08·23	00		87·18	3	κ
50·909	1		29·257	0		07·527	5	η	86·84	3	μ
50·309	10	εκ	29·065	0		07·041	3	θ	86·05	1	
49·976	4	ζ	28·77	0		06·759	3	ε	85·57	0	
49·688	5n	μ	28·646	1n	ρ	06·422	3	ζ	85·365	3	ε
48·927	1d?		28·280	1		05·899	2		85·03	2	ζ
48·433	3	κ	28·040	1	σ	05·52	1		84·83	2	
47·925	3	μ	27·78	00		05·050	3	κ	84·10	0	
47·638	1		27·512	3	κ	04·720	4	μρ	83·40	0	
47·09	2n		27·120	5	μ	04·250	2	σ	83·140	5	ηρ
46·689	7	ε	26·81	0		03·98	0		82·682	5	θσ
46·359	7	ζκ	26·36	1n		03·56	0		82·37	2	κ
45·938	3	μ	26·003	4	ε	03·36	0		82·02	2	μ
45·52	00		25·664	5	ζ	02·836	3		81·54	0	
45·368	5		25·32	000		02·456	2		81·26	3	
45·14	00		25·20	000		02·13	0		80·89	3	
44·840	4		24·738	1		01·84	0		80·34	0	
44·196	6	κ	24·547	2	η	01·590	7	εη	80·06	00	
43·780	4	μ	24·26	00		01·240	4	ζ	79·700	3	ε
43·31	00		24·135	9	κθρ	01·126	3	θ	79·390	3	ζ
42·868	7	ε	23·790	2	μ	00·800	2	κ	79·02	1	
42·511	6	ζ	23·560	2	σ	5100·433	2	μ	78·21	0	
41·862	4	κ	22·965	3		5099·99	0		77·95	00	
41·438	4	μ	22·436	3		99·72	00		77·50	3	κρ
41·22	0		22·03	00		99·576	3	ρ	77·091	4	μσ
40·376	5		21·57	00		99·204	2		76·755	4	η
39·874	4		21·404	4	ε	99·06	2	σ	76·295	4	θ
39·316	4	κ	21·046	5	ζ	98·39	1		76·09	0	
38·885	8	εμ	20·644	3	κ	97·99	0		75·54	1	
38·537	6	ζ	20·277	3	μ	97·05	1		75·15	0	
38·19	00		19·92	0		96·335	7	εκ	74·20	00	
37·64	00		19·515	2	ρ	95·990	5	ζμ	73·940	3d?	ε
37·193	3n		18·975	8	ησ	95·548	3	η	73·597	2	ζ
36·615	5	κ	18·510	6	θ	95·32	0		73·35	00	
36·213	5	μ	17·65	0		95·069	4	θ	72·99	1n	
35·86	00		16·963	3	κ	94·78	0		72·58	1n	
35·255	5		16·636	7	εμ	94·51	0		72·41	1n	κ
5134·755	9	ε	5116·327	3	ζ	5094·207	2	ρ	5072·01	2	μ

† The intensities of these lines are slightly increased by "ghosts" of the *b* lines.

Green Fluting (continued).

λ.	Int.	Series.	λ.	Int.	Series.	λ.	Int.	Series.	λ.	Int.	Series.
5071·76	2	ρ	5048·00	0		5025·77	000		5000·46	2	
71·31	2	σ	47·60	2	ρ	25·42	000		00·17	0	
71·08	0		47·19	2	σ	24·97	000		4999·81	0	
70·60	1		46·94	00		24·03	1	ε	99·64	0	
70·28	3	η	46·49	1		23·60	0	ζ	99·05	0	
69·81	3	θ	46·17	0		23·52	0		98·69	000	
69·27	1		45·72	0d?		23·18	1		98·23	00	
68·60	1		45·36	0		22·62	3	η	97·90	00	
68·18	1		44·99	0		22·12	3	θ	97·44	00	
68·066	2	ε	44·58	0		21·70	1		96·94	0	
67·713	1	ζ	44·32	1		21·40	000		96·76	1	
67·21	1n	κ	44·00	0		20·72	1		96·39	000	
66·86	1n	μ	43·500	4	εη	20·37	1		95·93	000	
66·13	00		43·052	3	ζθ	19·60	00		95·46	3	
65·88	3	ρ	42·14	00		19·05	0		95·03	3	
65·44	3	σ	41·69	1		18·65	1		94·51	000	
65·00	0		41·34	2	ρ	18·45	000		94·31	00	
64·50	0		40·94	2	σ	18·17	000		93·97	2	η
64·01	1		40·53	0		17·95	1		93·53	2	θ
63·697	3	η	40·34	0		17·52	1d?	ε	92·56	0n	
63·255	2	θ	39·98	000		17·09	0	ζ	92·04	0n	
62·63	00		39·63	2		16·54	000		90·71	000	
62·39	1		39·31	2		16·00	0		90·15	0	
62·06	1	ε	38·89	00		15·53	3	η	89·70	1d?	
61·94	2	κ	38·47	1		15·10	3	θ	89·28	0	
61·66	1n	ζμ	37·62	1		14·73	0		88·82	1	
60·63	1		37·07	2	ε	14·04	00		88·46	1	
60·19	1		36·67	1	ζ	13·59	00		88·04	00	
59·870	2	ρ	36·61	3	η	13·21	2		87·89	000	
59·436	3	σ	36·15	2	θ	12·74	00		87·27	0	
59·10	1		35·86	00		12·32	1		86·91	00	
58·71	0		35·45	00		11·94	1		86·68	2	η
58·44	0		35·07	1	ρ	11·68	00		86·24	2	θ
58·13	0		34·70	1	σ	10·88	00		84·95	00	
57·80	00		34·43	0		10·67	0	ε	84·03	1d?	
57·41	00		33·77	1		10·30	00	ζ	83·59	00	
57·060	4	η	33·62	0		09·82	2		83·16	00	
56·580	4	θ	33·43	0		09·42	00		82·97	0	
56·16	1		32·97	1n		09·01	2		82·50	00	
56·00	1	ε	32·46	1n		08·63	1		82·22	1	
55·60	1	ζ	32·16	1		08·39	2	η	81·92	1	
55·24	0		31·68	1		07·93	2	θ	81·69	0	
54·81	1n		31·38	00		07·42	000		81·32	00	
54·48	1		31·02	00		06·89	00		80·75	00	
54·15	0		30·61	1	ε	06·53	0		79·97	000	
53·79	2	ρ	30·25	1	ζ	06·14	0		79·36	2	η
53·36	2	σ	29·65	3	η	05·41	0		78·94	2	θ
53·20	0		29·17	3	θ	04·25	0		78·07	00	
52·60	00		28·54	1n	ρ	03·91	0	ε	76·88	0n	
52·03	00		28·13	0	σ	03·57	0	ζ	76·43	00	
50·92	1		27·85	0		03·14	2		76·09	00	
50·66	1		27·51	0		02·72	0		75·72	000	
50·320	3	η	27·28	00		01·68	00		75·10	1	
49·810	5d?	εθ	26·92	000		01·41	2		74·40	00	
49·419	2	ζ	26·53	2		01·23	2	η	74·25	0n	
5048·81	00		5026·12	1		5000·70	2	θ	4973·83	000	

Green Fluting (continued).

λ.	Int.	Series.	λ.	Int.	Series.	λ.	Int.	Series.	λ.	Int.	Series.
4973·36	000		4955·52	1		4930·36	00		4897·60	000	
72·51	000		54·93	00		29·84	00		96·78	000	
71·97	2	η	54·37	000		29·36	00		95·33	0n	
71·55	2	θ	53·17	000		27·69	0		94·73	00	
70·88	0n		52·48	00n		25·89	0		91·11	00	
70·54	000		51·96	00		25·21	0d ?		90·16	0	
70·18	0		51·38	00		24·73	0		88·05	0	
70·08	0		50·74	2		23·32	1		87·47	0	
69·61	0		49·84	000		22·55	0		86·05	00	
69·38	00		48·64	00		21·38	00		85·15	00	
69·11	00		47·72	00n		20·30	1		84·39	000	
68·74	0		46·72	00n		19·97	0		83·89	000	
68·57	00		46·38	00		19·66	00		83·75	0	
68·01	2d ?		45·90	0		19·26	0		83·34	00	
67·58	0		45·36	0d ?		19·03	0		80·79	00	
66·99	00		44·93	00		18·71	0		76·50	0	
66·04	00		44·10	0		17·09	000		75·45	00	
65·41	000		43·42	000		16·19	000		74·90	00	
65·25	00		42·80	0		15·70	00		74·64	0	
64·66	2	η ?	42·48	1		15·30	00		74·03	000	
64·24	2	θ ?	42·09	1		15·16	0		73·50	000	
64·06	0		41·36	0		13·68	00		72·56	00n	
63·45	0n		40·33	0		13·39	1		71·63	1	
63·29	0n		39·99	0		13·13	0		71·04	000	
62·80	0		39·13	0		12·33	000		70·41	0	
62·09	00		38·61	0		06·88	000		61·93	000	
61·72	00		37·85	00		06·57	0		60·49	00n	
61·48	1		37·02	000		06·27	000		60·08	00	
61·19	1		36·59	0		04·99	1		59·16	00	
60·45	000		36·39	000		04·60	0		54·90	000	
59·88	00		36·06	0		02·85	0		50·41	0n	
58·92	000		35·93	000		02·20	1d ?		48·08	00	
58·50	00		35·19	1		01·57	0		47·65	00	
57·92	1		34·79	2		4900·69	0d ?		46·38	00	
57·76	0		33·91	0n		4899·97	000		45·78	00n	
57·32	1	η ?	33·07	0n		99·32	0		4845·27	0	
56·93	1	θ ?	32·52	0n		98·62	1				
4956·29	000		4930·95	0n		4898·40	0				

Blue Fluting.

λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.
4844·92	2	4842·15	2	4838·86	0	4836·68	0	4833·54	0
44·65	3d ?	41·88	2	38·56	3	36·30	1	33·31	0
44·27	0	41·50	0	38·26	0	36·04	3	33·11	2
44·00	0	41·11	1	38·01	00	35·92	1	32·93	0
43·67	2d ?	40·68	1	37·83	1	35·44	3	32·66	0
43·19	2	40·28	1	37·50	00	35·01	0	32·26	1
42·69	0	39·80	1	37·09	4	34·52	3	31·89	0
4842·56	1	4839·30	2	4836·85	00	4834·06	3	4831·57	1

Blue Fluting (continued).

λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.
4831·12	2	4810·40	0	4787·91	1	4770·40	1	4748·13	1 } d?
30·76	1	10·19	1	87·65	1	70·11	3	48·02	1 } d?
30·46	00	09·74	1	87·31	0	69·79	1	47·59	1
29·97	5	09·04	0	87·07	1	69·42	1	47·38	00
29·55	3	08·67	1	86·76	1	69·00	1	47·19	1
29·14	00	08·10	1	86·51	2	68·51	0	46·36	00
28·78	3	07·78	0	86·28	1	68·26	2	46·12	0
28·55	00	07·00	3	85·89	1	68·02	1	45·86	2
28·31	2	06·26	1n	85·59	1	67·52	0d?	45·42	1
28·03	0	05·85	1	85·23	3	67·05	1	44·31	1
27·77	1	05·54	0	85·00	0	66·81	2	43·97	1
27·45	1	05·14	0	84·73	0	66·49	2	43·11	1
26·96	2n	04·79	0	84·46	3	66·14	1	42·87	00
26·47	2	04·31	1	84·06	3	65·76	00	42·58	0
26·10	0	03·76	2	83·72	1	65·24	1	42·23	1
25·98	2	03·45	1	83·29	2	65·07	0	41·90	2
25·76	0	03·10	1	82·95	1	64·69	2	41·22	0
25·51	0	02·63	3	82·53	1	64·36	00	41·02	1
25·19	0	02·41	0	82·12	1	63·94	1	40·68	3
24·72	3n	02·13	3	82·01	2	63·65	1	40·41	0
24·37	1	01·87	0	81·87	1	63·37	2	39·83	1
24·09	0	01·53	4	81·42	1d?	62·96	0n	38·99	00
23·79	0	00·97	3	81·06	0	62·56	1	38·66	1
23·12	2	00·43	1	80·86	2	62·45	0	38·25	1
23·00	2	4800·25	1	80·50	2	61·84	2	37·76	2
22·66	1	4799·73	2	80·24	0	61·23	0	37·43	0
22·54	00	99·49	3	80·03	2	60·93	0	37·17	0
22·16	0	99·03	1	79·65	1	60·66	1	36·62	00
21·77	3	98·62	3	79·55	1	60·21	1	36·33	0
21·51	1	98·22	3	79·26	1	59·95	0 } d?	35·79	0
21·22	00	97·74	3	79·13	1	59·83	0 } d?	34·99	0
21·07	0	97·35	3	78·86	0	59·47	2	34·85	0
20·63	0	96·76	3	78·56	2	59·21	0	34·62	1
20·44	0	96·37	3	78·17	2	58·91	0	34·31	1
19·87	5d?	95·99	00	77·79	2d?	58·23	00	33·83	00
19·60	0	95·70	4	77·43	0	57·49	2	33·30	0
19·33	1	95·32	4	77·00	0	57·06	2	33·04	00
18·92	00	94·87	1	76·82	5	56·45	3	32·58	0
18·49	0	94·61	1d?	76·60	0	56·02	2	31·95	1
18·27	0	94·32	5d?	76·30	1	55·75	0	31·46	2
18·01	2	93·85	0d?	76·14	0	55·40	0	31·03	1n
17·51	1	93·42	0	75·84	0	54·63	00	30·56	0
16·67	2n	93·28	3d?	75·48	3	54·22	00	30·23	00
16·17	4	92·72	2	75·07	2d?	54·00	1	29·97	0
15·56	0	92·55	00	74·57	1	53·57	3	29·31	0
15·02	1	92·22	3	74·26	1	53·10	1	29·16	0
14·51	0	91·93	3	74·04	0	52·93	1	28·82	0n
14·26	1	91·51	1	73·71	2	52·54	1	28·63	00
14·07	0	91·24	1	73·45	2	52·02	0n	28·15	00
13·61	1	90·97	2	73·08	1d?	51·42	2	27·82	00
13·30	1	90·45	1	72·65	3	50·85	2	27·42	1
12·74	1	90·01	1	72·34	0	50·66	0	26·95	2
12·15	1d?	89·59	4	71·92	0	50·41	1	26·79	00
11·70	0	89·24	1d?	71·58	1	49·37	1	26·38	1
11·51	1	88·66	2	71·23	2	48·98	1	24·61	0
4810·89	1	4788·23	4	4770·85	1	4748·64	0	4724·30	3

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Blue Fluting (continued).

λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.
4723·93	1d ?	4694·57	0	4643·57	1	4554·26	1	4483·21	1n
23·20	00n	93·92	0	42·10	00	51·49	1	80·38	2
22·38	0	93·30	00	41·19	1	50·36	00	78·78	2
21·16	0	92·92	00n	40·36	0	46·66	0	76·61	1
20·97	1	92·68	0n	39·78	1	44·41	1	75·47	5
20·69	0	92·13	00	39·05	0	44·22	1	74·76	0
20·36	0	91·22	0n	35·10	0	42·73	2	73·83	00
20·00	00	90·90	00	34·13	00	42·05	00n	73·21	1
19·58	00	90·58	0n	33·84	1	41·31	00	70·91	1
19·24	1	90·16	0	33·12	00	40·25	00	70·16	00
18·48	0	89·78	00	32·47	0	39·47	00	69·61	1
18·23	0	88·76	00	31·08	1	37·53	1d ?	66·75	1
17·97	0	88·20	00	28·98	0	35·00	0	64·35	0
17·80	0	87·67	1	28·60	0	34·40	0	63·44	1
17·38	0	87·21	00	25·33	0	33·95	1	61·03	1
17·04	1	86·87	0	24·64	0	31·98	2	60·49	0
16·58	2	86·71	0	24·15	1	30·46	2	58·97	1
15·89	1	86·27	0	23·69	00	29·49	00	58·28	1
15·74	0	86·00	0	22·95	0	25·65	00	55·62	0
14·97	00	85·73	0	21·78	1	23·31	1	52·92	0
14·47	00	85·13	00	18·70	0	20·67	2	51·62	00
13·85	1n	84·64	00	14·47	1	20·31	0	51·18	1
13·48	1	83·60	1	11·16	00	19·63	1	50·63	0
13·14	0	83·18	0n	10·20	0	19·18	1	50·19	00
12·19	00n	82·80	00	09·37	0n	17·85	0	47·56	1
11·68	00	82·52	0n	08·28	00	17·31	0	45·65	0
11·37	00	81·62	1	07·55	0	16·70	1	44·82	1
10·93	0	80·53	1	07·00	0	16·41	00	42·22	0
10·37	00	78·50	00n	06·46	0	15·94	1	41·88	0
09·90	1	75·70	1	05·86	1	14·93	00	40·63	00
09·58	0	75·05	00	03·60	1	14·46	00	40·16	00
09·08	1	74·49	1	03·19	00	13·85	1	35·90	1
08·40	1	73·48	00	02·91	00	13·34	1	32·91	0
07·82	1	73·26	00	4600·52	0	11·28	0	30·71	0n
07·31	0	72·43	00	4598·04	0	10·55	2	30·47	0n
06·93	0	67·61	0	94·20	0	09·18	1	29·70	1
06·44	1	67·44	00	93·02	0n	08·91	1	27·24	0n
06·17	1	66·75	0	90·55	00	06·61	00n	23·77	0
05·76	00	65·80	0	89·85	0	04·41	00	23·28	1
05·38	0	64·92	1	88·75	1	03·70	0	22·34	1
05·10	1	64·19	1	87·13	00	02·02	0	20·70	1
04·62	0n	63·80	0	86·61	1	01·50	2	19·42	0
02·71	0	62·88	00	84·56	0	4500·31	1	18·88	0
02·16	0	62·52	00	82·64	1	4499·63	00n	15·64	0
01·60	0	61·81	1	78·98	0	99·19	00n	14·66	0
01·10	00	59·22	0	77·61	00	98·49	0	14·04	1
00·75	1n	57·62	00	76·92	00n	97·06	2	13·46	1
4700·25	0	56·57	0	75·94	00n	94·95	00	10·26	0
4699·40	1	55·33	1	74·60	00	94·40	00	09·86	1
99·02	00	54·32	0	72·79	1	93·70	2d ?	09·60	00
97·45	0	53·97	00	66·33	0	92·58	1	07·16	1
96·94	0	53·62	00	65·83	00	90·30	2	04·95	1
96·12	0	46·97	1	61·79	00	89·10	1	03·90	1
95·79	00	46·06	0	59·50	1	86·72	1	02·77	2
95·35	00	45·69	0	58·04	1	85·92	2	01·52	0
4694·91	1	4644·54	00	4556·15	2	4485·38	1n	4400·70	1

Blue Fluting (continued).

λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.	λ.	Int.
4399·80	0	4395·05	00	4388·19	0	4383·79	1	4378·44	0
98·33	1n	94·09	0	87·84	00	83·02	00	78·12	1
98·13	00	93·30	1	87·47	00	80·57	0	73·78	0
96·63	1	90·00	0	86·17	00	80·20	1	72·35	00
4395·99	0	4389·04	1	4385·86	0	4378·98	0	4371·83*	0

* 1st line in violet fluting.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Description of Plates.

General Note.

In the process of enlargement a cylindrical lens has been used to broaden the spectra and smooth out irregularities produced by the grain of the gelatine films. Spurious lines due to grain have been introduced in this way, but they are probably too faint to appear in the reproductions. In case of doubt, comparison with the wave-length catalogue may be made.

PLATE 12.

A.—The first strip shows the three principal flutings of magnesium hydride, as photographed with the small Littrow spectrograph, and indicates their relative intensities more correctly than the other photographs, which have been copied in sections. The remaining strips give a general map of the spectrum from 5622 to 4600, as photographed in the first order of the 10-feet concave grating.

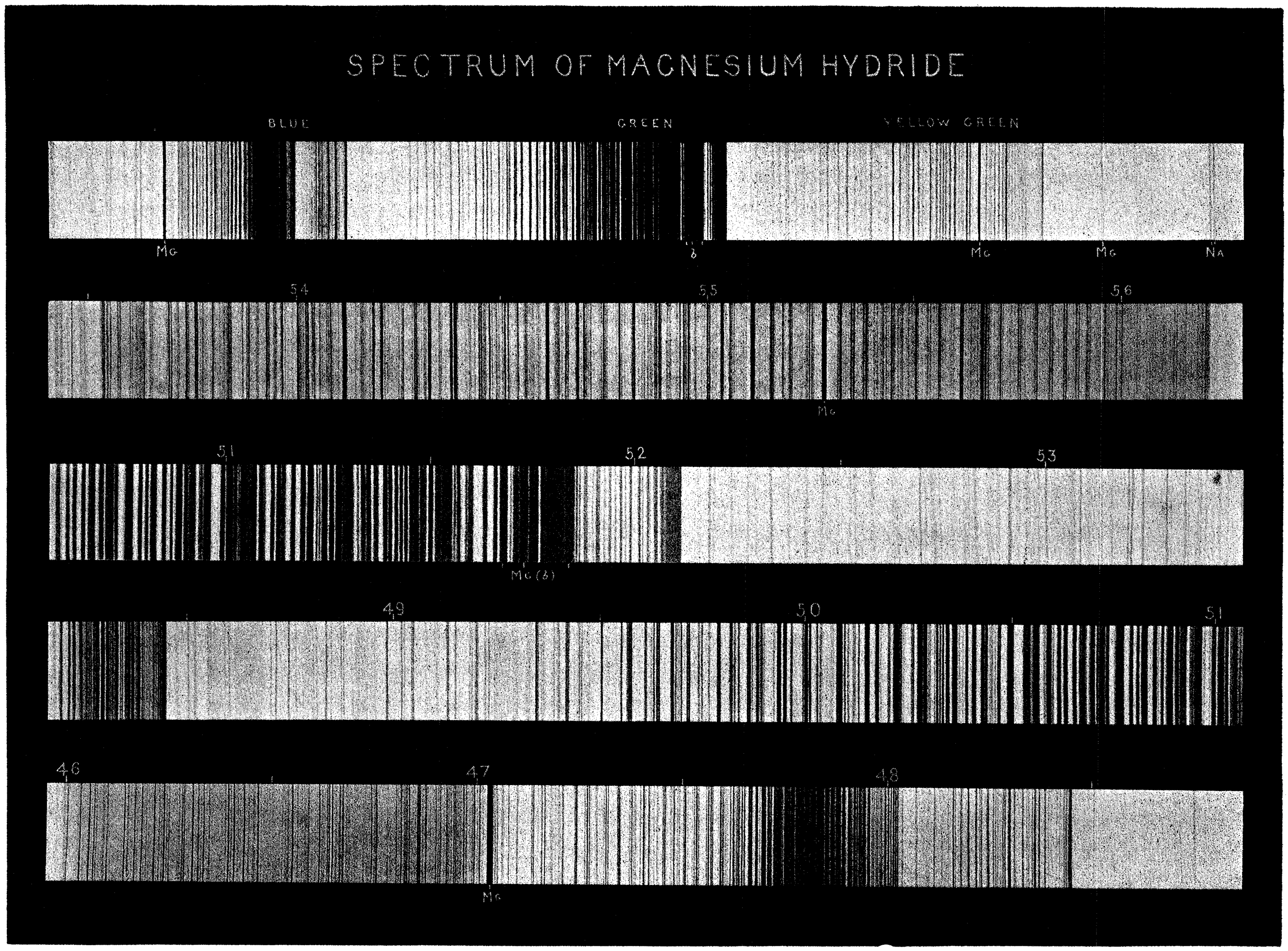
B.—The photographs show the brighter parts of the green fluting, as photographed with the concave grating in the second order. The principal series of lines which compose the fluting are also indicated.

PLATE 13.

Photographs demonstrating the presence of magnesium hydride in sun-spots. The photographs of the sun and sun-spot spectra were taken by Mr. Evershed at Kodaikanal (the exposure for the sun-spot was about six times that for the solar spectrum).

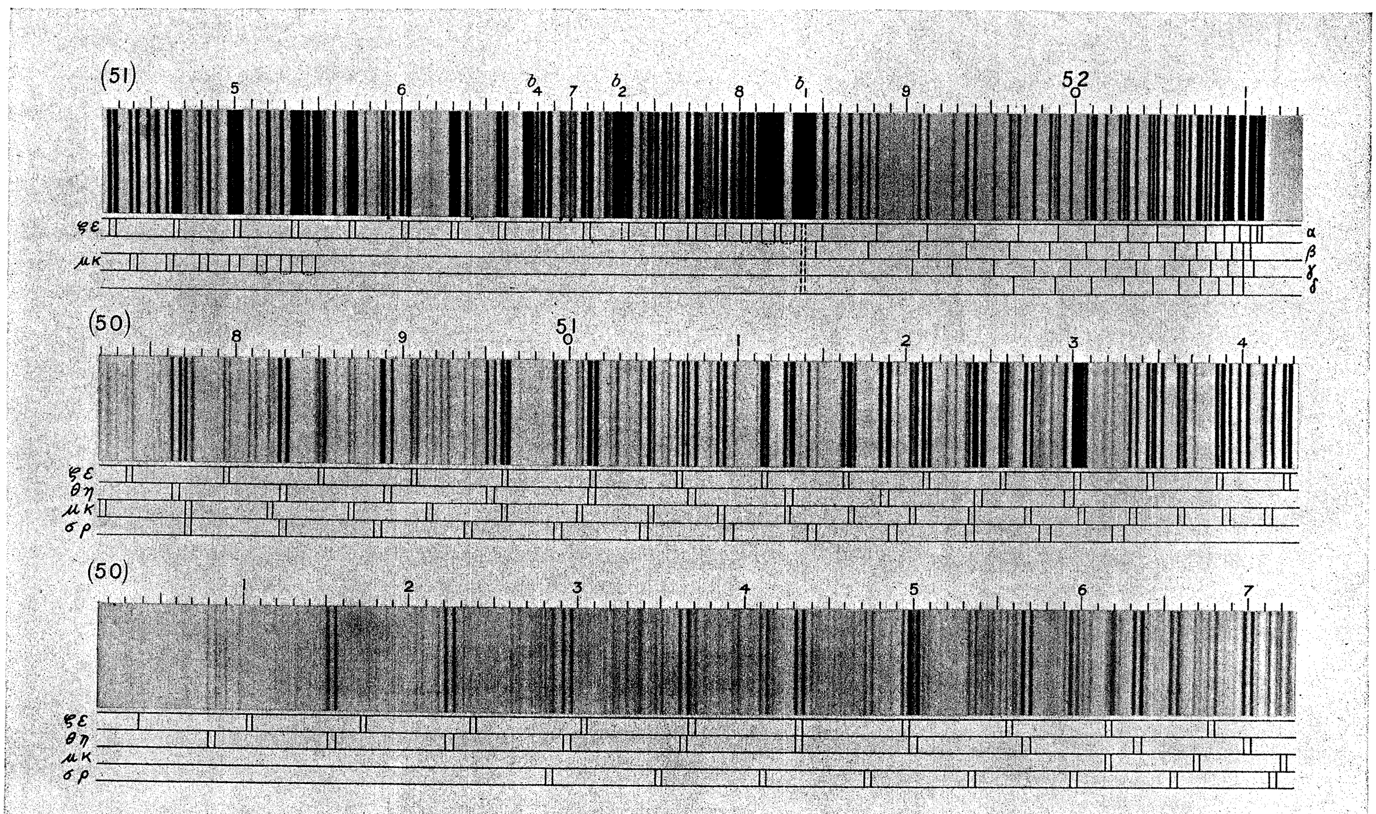
The lines marked with dots in Plates 12B, and 13 are "ghosts." Other lines affected by ghosts of the *b* group are indicated in the catalogue.

A

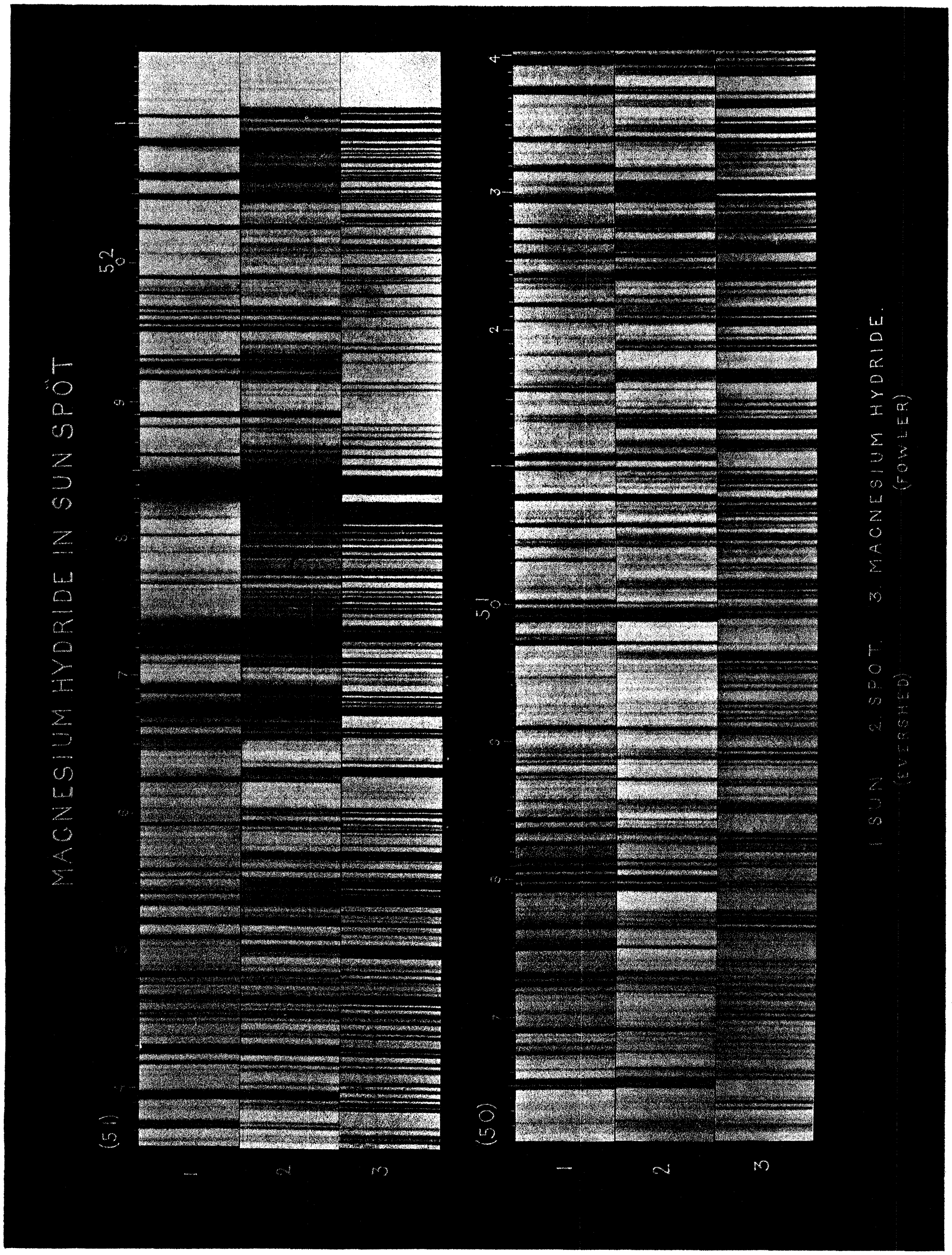


1 **2** **3** **4** **5**

B

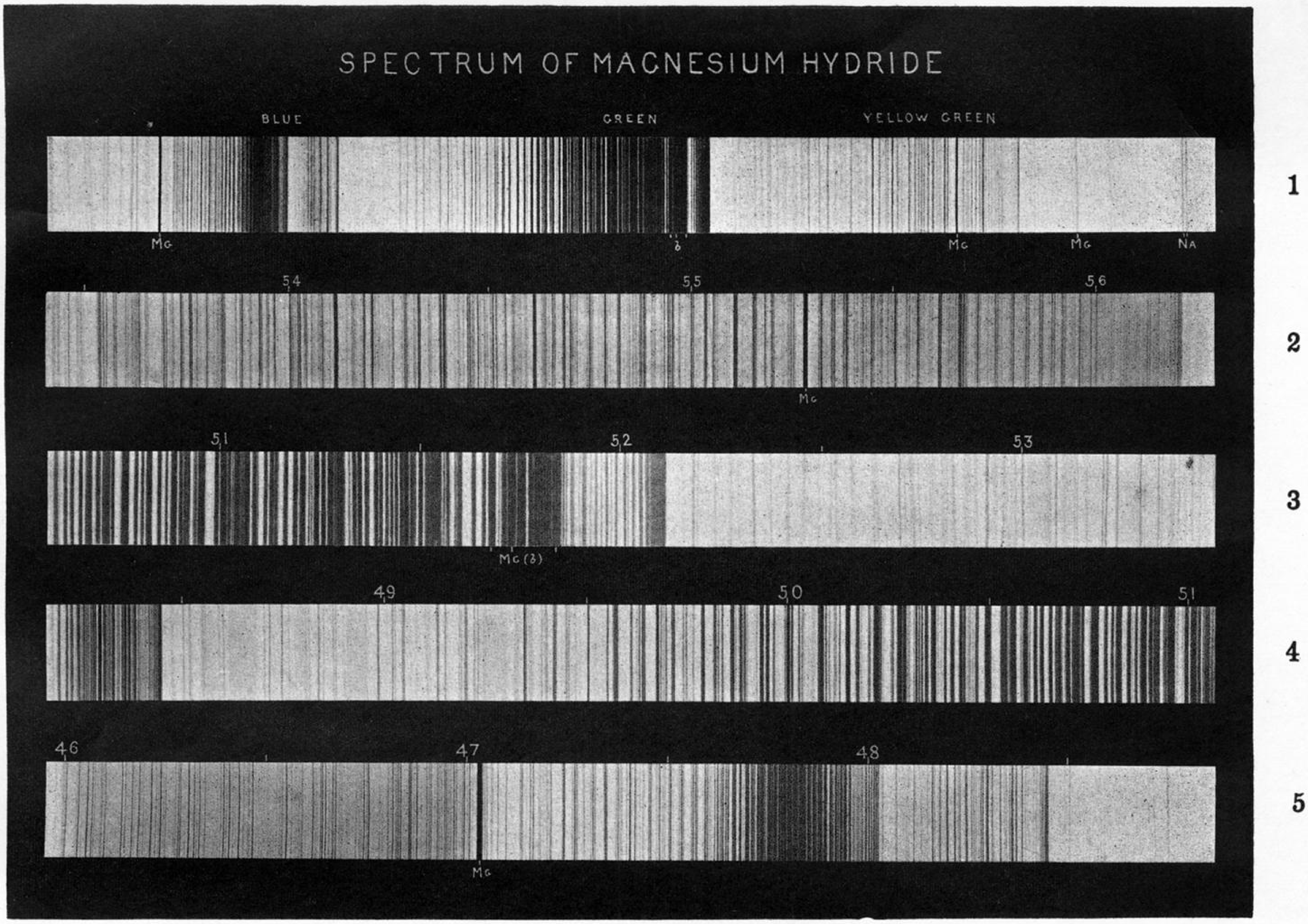


SERIES IN GREEN FLUTING OF MAGNESIUM HYDRIDE

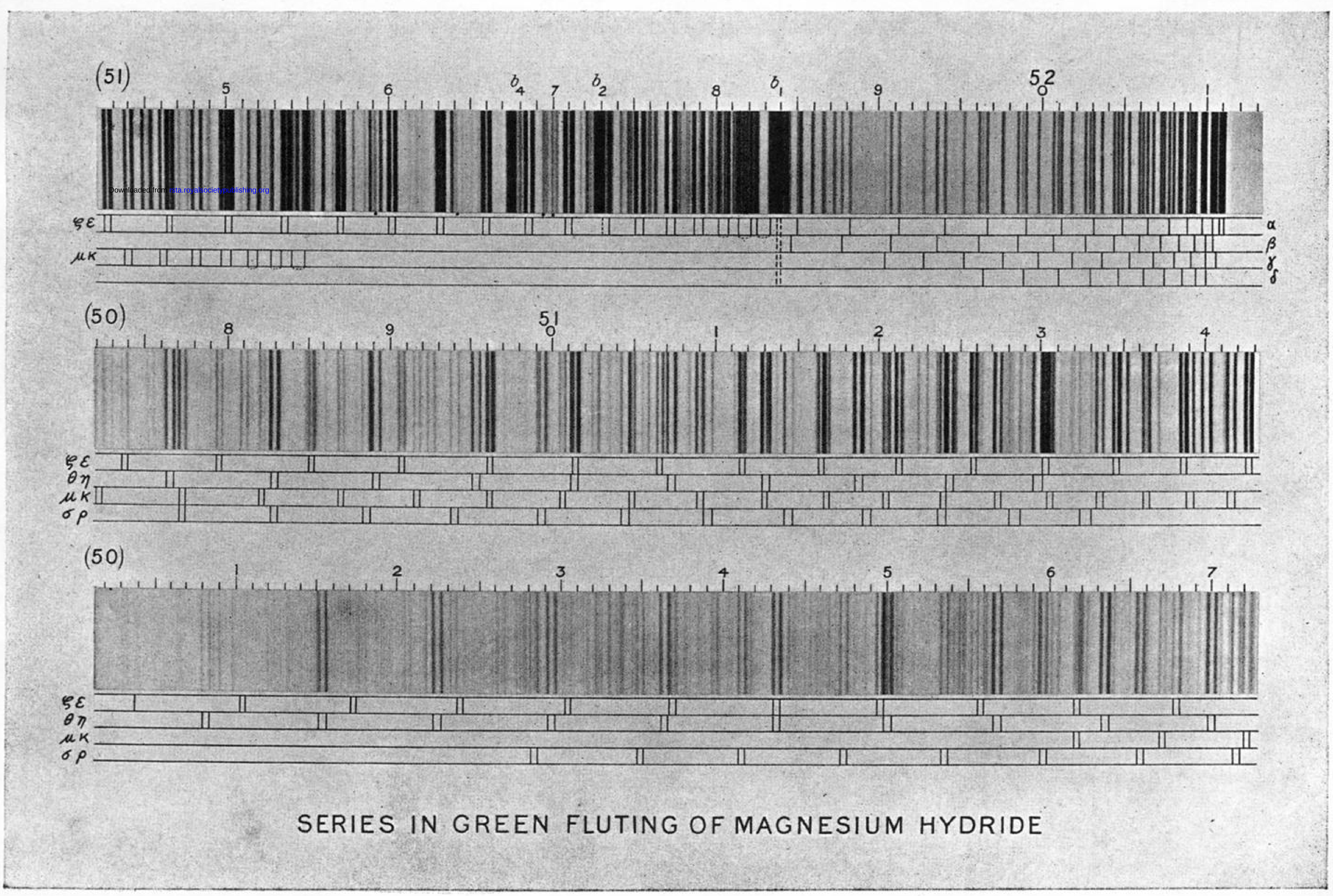


PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

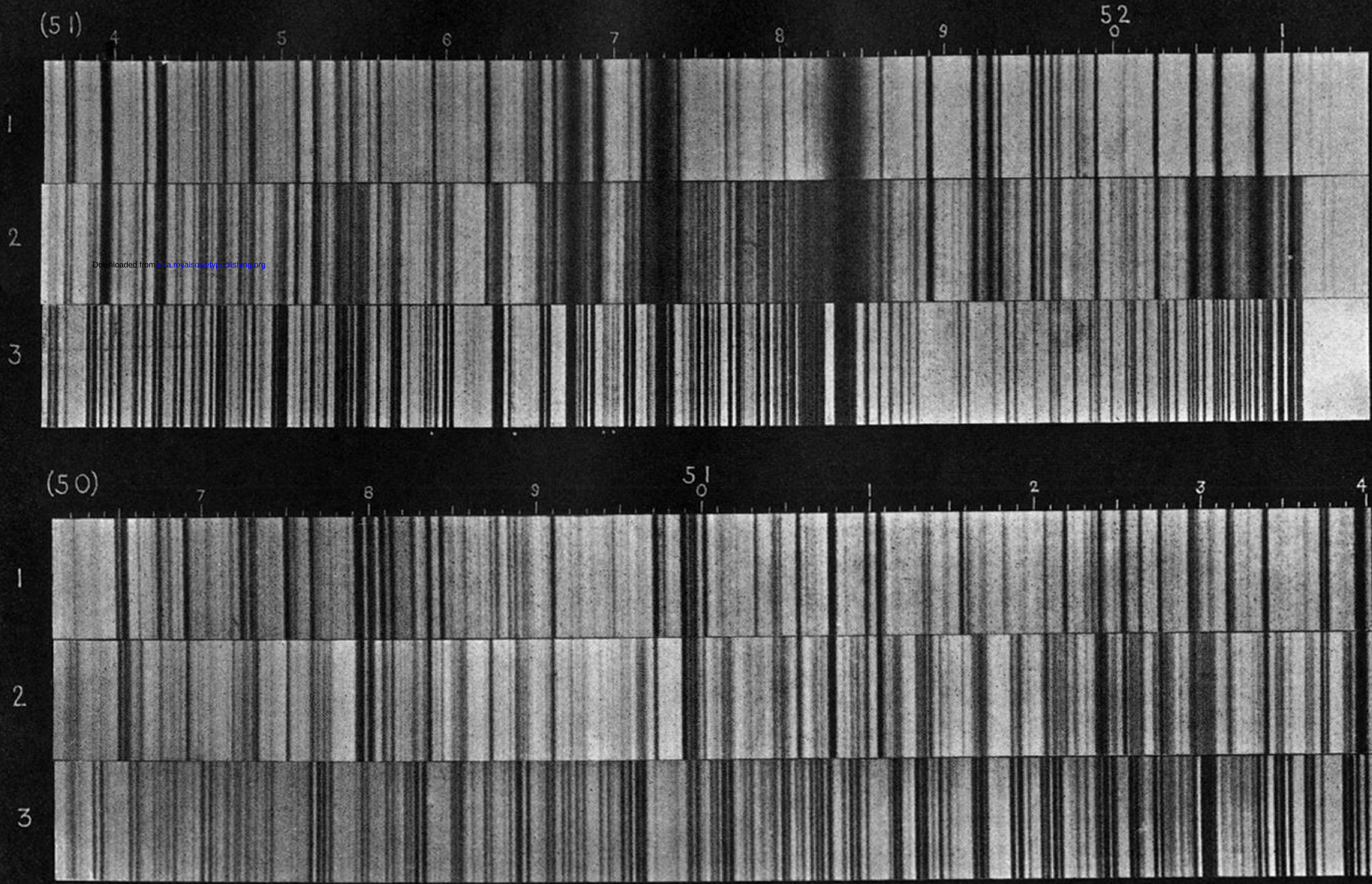
A


SPECTRUM OF MAGNESIUM HYDRIDE
BLUE
GREEN
YELLOW GREEN
1
Mg
b
Mg
Mg
Na
54
55
56
2
Mg
51
52
53
3
Mg (b)
49
50
51
4
46
47
48
5
Mg

B


(51)
5
6
b_4
7
b_2
8
b_1
9
52
1
φε
μκ
α
β
γ
δ
(50)
8
9
51
1
2
3
4
φε
θη
μκ
σρ
(50)
1
2
3
4
5
6
7
φε
θη
μκ
σρ
SERIES IN GREEN FLUTING OF MAGNESIUM HYDRIDE

MAGNESIUM HYDRIDE IN SUN SPOT



1. SUN. 2. SPOT. 3. MAGNESIUM HYDRIDE.
(EVERSHED) (FOWLER)