V. *Researches in Spectrum-Analysis in connexion with the Spectrum of the Sun.*

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THE researches of which an account is given in the present communication have been undertaken in continuation of those carried on by Dr. FRANKLAND and myself at the Royal College of Chemistry, from which we arrived at the conclusion that the thickening of spectral lines was due to pressure, and not to temperature *per se**. In our joint communications we pointed out that this held good for hydrogen in GEISSLER'S tubes and for magnesium vapour † when the spark was taken in air, by means of a method which enabled us to spectroscopically examine its various portions.

The magnesium experiment was important not only so far as the decrease of thickness of lines with decrease of density was concerned, but because it showed that one of the well-known triple lines in the spectrum of magnesium absolutely vanished altogether from the spectrum at some distance from the source of the supply of the vapour—that is, the pole of metallic magnesium. This result we also obtained, as stated in our note, when we observed the spectrum of the spark between two magnesium poles enclosed in a GEISSLER'S tube in an atmosphere of hydrogen in which the pressure of the gas was gradually reduced.

In some experiments with sodium vapour, which were not referred to in the papers in question ‡, Dr. FRANKLAND and myself observed the same phenomena. The experiments were conducted as follows:—

(1) Into a piece of hard glass combustion-tube, thoroughly cleaned and closed at one end, a few pieces of metallic sodium, clean and as free as possible from naphtha, were introduced. The end of the tube was then drawn out and connected with a Sprengel pump and exhausted as rapidly as possible. Hydrogen was then admitted, and the tube reexhausted and, when the pressure was again reduced to a few millimetres, carefully sealed up. The tube thus prepared was placed between the slit plate of a spectroscope and a source of light giving a continuous spectrum.

Generally, unless the atmosphere of the laboratory was very still and free from dust, the two bright D lines could be distinctly seen on the background of the bright continuous spectrum.

The tube containing the sodium was then heated with a Bunsen flame and the spectrum carefully watched. Soon after the application of the heat, a dark line thin, and delicate as a spider's thread, was observed to be slowly creeping down each of the bright

* Proceedings of the Royal Society, vol. xvii. p. 289. † Ibid. vol. xviii. p. 79.

‡ This experiment was first exhibited at a Lecture given by me at the Royal Institution in May, 1869.

sodium lines and exactly occupying the centre of each. Next, this thin black line was observed to thicken at the *top*, where the spectrum of the *lower* denser vapours was observed, and to advance downwards along the D line, until arriving at the bottom they both became black throughout; and if now the heat was still applied, thus increasing the density of the various layers of the sodium vapour, the lines began to broaden until, in spite of considerable dispersion, the two lines blended into one. The source of heat being now removed, the same changes occurred in inverse order; the broad band split into two lines, gradually the black thread alone was left, and finally that vanished, and the two bright lines were restored.

(2) This experiment was then varied in the following way. Some pieces of metallic sodium were introduced into a test-tube, and a long glass tube conveying coal-gas passed to the bottom, an exit for the gas being also provided at the top. The sodium was now heated and the flow of coal-gas stopped. In a short time the reversal of the D lines was complete. The gas was now admitted, and a small quantity only had passed when the black lines were reduced to threads.

In my former communications to the Royal Society I have pointed out the extreme importance of these facts in connexion with solar and stellar physics. In observing the sun by the new method, we get various Fraunhofer lines thickened in the spots and thinned in the chromosphere and prominences; and in these latter, in some instances, notably in the case of F, we find the lines gradually widening as they approach the limb of the sun.

While this may be remarked as a solar demonstration of the correctness of the conclusion at which Dr. FRANKLAND and myself had arrived, it is to be noted that bright line prominences may occasionally be seen on the sun's disk over or near spots in the spectrum of which the same lines are thick, while this phenomenon could not exist if the thickening of the lines were due to temperature alone.

*Method employed**.

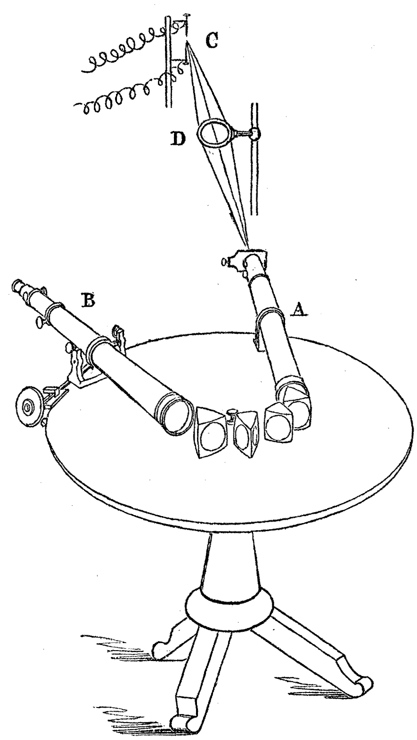
The method of observing spectra to which I have already referred, and which has been adopted in the work of which I now propose to give an account, consists in throwing an image of the spark on the slit of a spectroscope in the laboratory experiments in exactly the same manner in which I proposed, in 1866, that an image of the sun should be thrown on the slit in order to spectroscopically examine minute portions of the sun and his surrounding atmosphere.

It is obvious that in this method the image of the slit will be associated in the spectroscope with an image of a section of the spark, and that if from any cause there be various shells of vapour surrounding each pole, which shells give different spectra, then these spectra will be sorted out so that their variations may be traced from pole to pole.

* This method was first exhibited at a lecture at the Royal Institution, April 2nd, 1870. The same method has more recently been employed with great success by M. SALET in a research on the spectra of the metalloids.

The arrangements adopted will be easily gathered from the annexed woodcut (fig. 1) and the accompanying description. It is scarcely necessary to add that an important condition of this new method is that the object-glass of the collimator should be filled with light, and also that no light should be wasted. So long as these conditions obtain, conjugate foci and different lenses may be employed and the size of the image varied at pleasure, and still the brightness of the spectrum will be sufficient.

Fig. 1.



A. Collimator. C. Spark.
B. Observing Telescope. D. Lens.

The instruments with which the observations have been made are as follows :—

A large spectroscope, a sister instrument to that used by BUNSEN and KIRCHHOFF in their celebrated researches, and made by the same maker, STEINHEIL of Munich*. It is furnished with four prisms of flint glass. Three are of an angle of 45° and one of 60°. The general arrangements of the instruments are described by KIRCHHOFF in his memoir.

In front of the slit plate is placed a lens throwing on the slit the image of the spark.

A coil, made by APPS and giving a 4-inch spark.

A large Leyden jar has also been occasionally used as a condenser on the secondary wire.

Beneath the observing-telescope is placed a commutator, by which the current is controlled by the observer without changing his position.

The window of my laboratory looks due south, and the collimator is placed in the same direction; and when it became necessary to have the solar spectrum in the field, the light reflected from a heliostat placed outside the laboratory in direct prolongation of the line of collimation was thrown on to the lens and thus on to the slit, where the size and intensity of the images could be varied at pleasure by altering the position of the lens.

When it was required to photograph a spectrum, the ordinary observing-telescope of the spectroscope was dismounted, and its place supplied by a telescope of $3\frac{3}{4}$ inches aperture and 49 inches focus. This was supported on the cast-iron table of the spectroscope at one end and at the other on a stand. The eyepiece and its mounting were removed, and against the end of the tube, thus left free, a small camera-box, holding a plate $4\frac{1}{4}$ in. by $3\frac{1}{4}$ in., was placed, and the photograph taken in the usual manner, the focus being obtained partly by careful observation with powerful magnifiers and partly by trial plates.

* This spectroscope has been temporarily placed at my disposal by Professor GUTHRIE, of the Royal School of Mines, to whom my best thanks are due.

From the time of WHEATSTONE'S first experiments, when in 1835 he stated that if the poles consisted of two different metals the spectrum contained the lines of both metals, down to the researches of STOKES, MILLER, and ROBINSON in 1862, there is no reference, so far as I can find, to any localization of light in any portion of the *breadth* of the spectrum. In the case of the spark taken between two poles, *e. g.* in air, the spectrum is generally one in which the lines of the two vapours and of air are blended together, all the lines running across the field.

But under certain conditions this is not so. Thus STOKES*, who used the spark itself instead of a slit, remarked that the metallic lines are "distinguished from air lines by being formed only at an almost insensible distance from the tips of the electrodes, whereas air lines would extend right across."

MILLER†, who used a slit and a spark close to it, referring to his photographs of electric spectra, remarks, "the marginal extremities of the metallic lines leave a stronger image than their central portions," and the extremities of these interrupted lines he terms "dots."

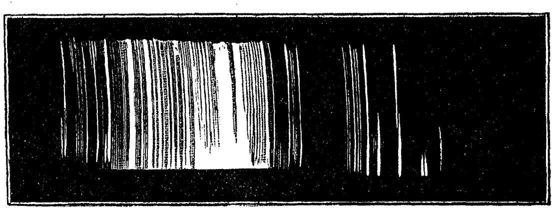
On the same subject ROBINSON‡ writes, "At that boundary of the spectrum which corresponds to the negative electrode (and in a much less degree at the positive) extremely intense lines are seen, . . . which, however, are short."

THALÉN (though he also did not adopt the method used by Dr. FRANKLAND and myself in and since 1869) observed this localization to a certain extent, doubtless on account of the long collimator which he employed.

He remarks §:—"Il y a aussi des raies brillantes qu'on n'observe que dans des cas exceptionnels, comme, par exemple, quand la quantité de la substance soumise à l'expérience est très-abondante ou quand l'incandescence devient très-vive. Ces raies qui se présentent ordinairement aux bords du spectre sous la forme de points d'aiguille, même quand les autres raies du métal forment des lignes continues en travers du spectre, ont été représentées sur la planche par des lignes très-courtes."

Before I proceed further I beg to refer to the two annexed woodcuts (figs. 2, 3), copied

Fig. 2.



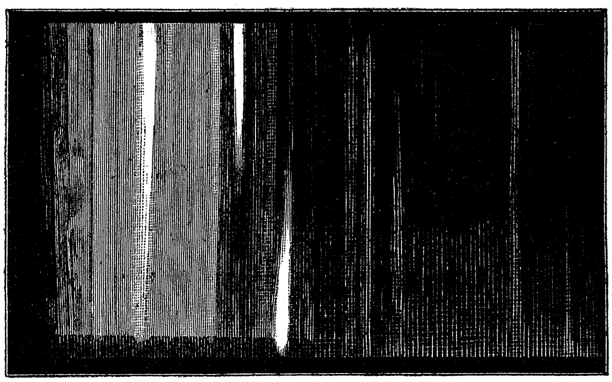
from photographs of a part of the spectrum observed when the jar-spark passes (1) between the poles of *zinc* and *cadmium*, and (2) between *cadmium* and *lead*, and the image is thrown on the slit. It will be seen that in the case of these metallic vapours (and it is true of

* Philosophical Transactions, vol. clii. 1862, p. 603. † *Op. cit.* p. 877. ‡ *Op. cit.* p. 947.

§ "Mémoire sur la détermination des longueurs d'onde des raies métalliques," p. 12, printed in the Nova Acta Regiæ Societatis Scientiarum Upsaliensis, ser. iii. vol. vi. Upsala, 1868.

all others that I have yet observed) the lines as in the before-mentioned case of the triple line (*b*) of magnesium, are of unequal length, and that in the new method of

Fig. 3.



observation the lines in the spectra of the two metallic vapours and of the air are separated in the clearest and most convenient manner, the air lines going right across, and the lines of the metallic vapours extending to greater or less distances from each pole, and in some cases (*i. e.* of the longest lines) overlapping.

With this communication are maps (Plates XI., XII., XIII.) of the spectra of the following elements made on this method, the jar being used:—Na, Li, Mg, Al, Mn, Co, Ni, Zn, Sr, Cd, Sn, Sb, Ba, and Pb. The lines were laid down from THALÉN'S maps, given in the memoir quoted above and on the same scale, namely 2 centimetres to each $\frac{1}{100000}$ millim. of wave-length. The spectra were then carefully and repeatedly observed, and the comparative lengths of the lines estimated and laid down over their respective wave-lengths

At the same time that these spectra have been mapped with the spark taken in air, many of them have also been observed when their metals were enclosed in tubes and subjected to a continually decreasing pressure, as in the case of the before-mentioned experiment with magnesium. *In all these experiments it was found that the longest lines invariably remained visible longest.*

In the case of zinc the effect of these circumstances was very marked, and they may be given as a sample of the phenomena generally observed. When the pressure-gauge connected with the Sprengel pump stood at from 35 to 40 millimetres, the spectrum at the part observed was normal, except that the two lines 4924 and 4911 * (both of which, when the spectrum is observed under the normal pressure, are lines with thick wings) were considerably reduced in width. On the pump being started these lines rapidly decreased in length, as did the line at 4679,—4810 and 4721 being almost unaffected; at last the two at 4924 and 4911 vanished, as did 4679, and appeared only at intervals as spots on the poles, the two 4810 and 4721 remaining little changed in length though much in brilliancy. This experiment was repeated four times, and on each occasion the gauge was found to be almost at the same point, viz.:—

* THALÉN'S scale as given by WATTS.

1st observation, when the lines 4924 and 4911 were gone the gauge stood at				30	millimetres.
2nd	,,	,,	,,	29	,,
3rd	,,	,,	,,	29	,,
4th	,,	,,	,,	31	,,

A rise to 34 millimetres was sufficient to restore the lost lines.

Experiments with Chemical Compounds.

Since it appeared that the purest and densest vapour alone gave the greatest number of lines, or, in other words, that the truly complete spectrum of a body is alone to be obtained upon the metallic pole itself where the vapour is densest and purest, it became of interest to examine the spectrum of a compound consisting of a metal combined with a non-metallic element.

To this end a number of experiments were made, in which the metallic spectra were compared with those given by the same metals when combined with chlorine under the same conditions as in the former experiments.

The compounds thus experimented on were as follows, the jar being used:—Li Cl, Na Cl, $Mg\ Cl_2$, $Zn\ Cl_2$, $Sr\ Cl_2$, $Cd\ Cl_2$, $Ba\ Cl_2$, $Pb\ Cl_2$, and $Al_2\ Cl_6$. It was found in all cases that the difference between the spectrum of the chloride and the spectrum of the metal was:—*That under the same spark-conditions the short lines were obliterated, while the air lines remained unchanged in thickness.*

Changing the spark-conditions by throwing the jar out of the circuit, this change was shown in its strongest form, the final results being that only the very longest lines in the spectrum of the metal remained.

The following are the details of the experiments made under these conditions:—

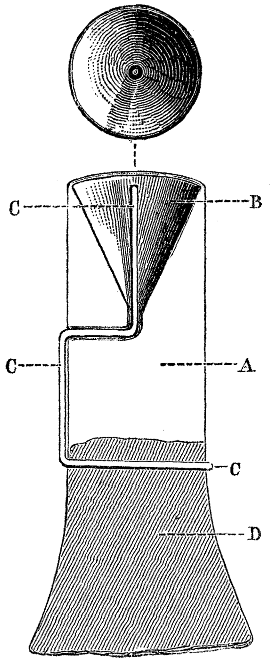
Method of Observation.—Some pieces of stout aluminium wire 10 millims. long and 3 millims. in diameter were taken; one end was flattened for about one third of the length for the purpose of inserting it in the spark-holder, and the other was drilled down in the direction of the axis for from 2 to 3 millims., and thus formed into a small conical cup; a very fine hole was then drilled through the side of this cup at the bottom and the flattened end carefully split. Through the lateral hole a piece of platinum wire 0·5 millim. in diameter was passed and one end brought round through the split end of the aluminium, while the other was brought up the centre of the cup. The split was now closed by strong pressure in a vice, and the ends of the platinum wire cut off. The whole now presented the appearance of a small candle, the platinum wire representing the wick: the accompanying figures (figs. 4, 5) will render the preceding statement clear*. Round this wick the chloride in fine powder was tightly rammed down. [A similar cup, without the wick, was used for the examination of the spectra of metallic barium, strontium, and lithium,

* The object of the wick was to confine the spark to the centre of the dry chloride. Before it was adopted the spark was very unsteady, leaping about from side to side of the cup.

the metal being hammered into it.] One of these cups with the chloride replaced the lower pole in the spark-holder, the upper one being composed of copper, that metal

Fig. 4.

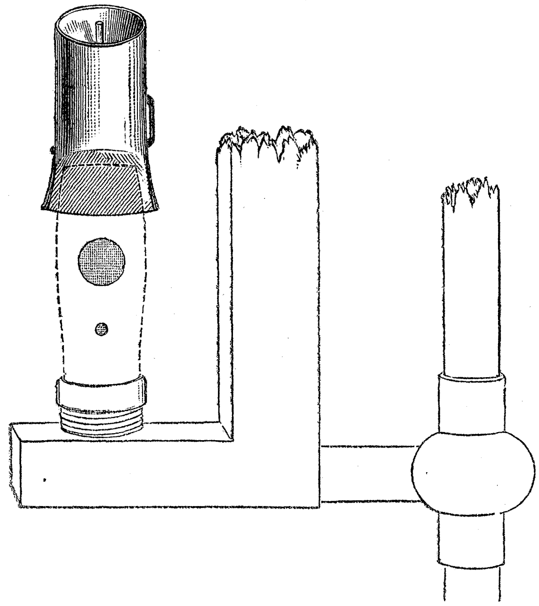
Plan and section of cup used with salts.



A. Aluminium wire.
B. Cup-shaped cavity drilled in it.
C. Platinum wire.
D. Flattened and split portion of the aluminium wire.

Fig. 5.

Aluminium cup placed in the spark-stand as in use.



being selected as being a good conductor and giving a very simple and easily recognized spectrum.

Chlorides observed. Lithic Chloride, Li Cl.—The wave-lengths of the longest lines of this metal are as follows:—6705·2, 6102·0, and 4602·7, the latter (in the blue) being a wide and winged line. When the spectrum of the chloride is observed, the red line 6705·2 is seen right across the spectrum, the orange, 6102·0, is faintly visible for about half the distance; 4602·7 has vanished altogether. In the case of lithium this extinction can be carried further in the flame reaction with an ordinary Bunsen burner, in which the red line 6705·2 is alone seen*.

Sodic Chloride, Na Cl.—The D line $\left.\begin{matrix}5895{\cdot}0\\5889{\cdot}0\end{matrix}\right\}$ is by very far the longest line in the sodium spectrum; it is, in fact, the longest metallic line I have observed. After D

* It is necessary in dealing with Li Cl and Na Cl to have the poles rather far apart (8 to 10 millims.), as, on account of the easy volatility of these chlorides, if the poles are close all the lines appear stretching across the spectrum.

come $\left.\begin{matrix}6160{\cdot}0\\6154{\cdot}2\end{matrix}\right\}$ in the red and $\left.\begin{matrix}5687{\cdot}2\\5681{\cdot}4\end{matrix}\right\}$ in the yellow, the latter pair having a slight advantage over the former. $\left.\begin{matrix}5154{\cdot}8\\5152{\cdot}5\end{matrix}\right\}$ come next, and the shortest is 4982·5, really a double line, but so nebulous and ill-defined that THALÉN has represented it as single. In the chloride we find D $\left.\begin{matrix}5895{\cdot}0\\5889{\cdot}0\end{matrix}\right\}$ all across the spectrum, and all the others have vanished but a trace of $\left.\begin{matrix}5687{\cdot}2\\5681{\cdot}4\end{matrix}\right\}$.

Magnesic Chloride, $Mg\ Cl_2$.—Magnesium has three lines (*b*) surpassing all the others in length; their wave-lengths are 5183·0, 5172·0, and 5166·7: these lines alone are constant in the chloride; 4481·0, the winged line, sometimes flashes in.

Zincic Chloride, $Zn\ Cl_2$.—Zinc has three long lines in the blue, 4809·7, 4721·4, 4679·5; these only are visible in the spectrum of the chloride. One line, 6362·5, in the extreme orange, is of the same length, apparently, as the shortest of the three blue lines, but is not visible, possibly on account of its faintness.

Strontic Chloride, $Sr\ Cl_2$.—Strontium has one extremely long line, 4607·5, and this with two in the indigo, 4226·3 and 4215·3, next in length to it, are alone seen in the chloride spectrum.

Cadmic Chloride, $Cd\ Cl_2$.—Cadmium, like zinc, has three lines of greater length than all the rest—one in the blue-green, 5085·0, and two, 4799·0 and 4676·8, in the blue. These alone appear in the spectrum of the chloride.

Plumbic Chloride, $Pb\ Cl_2$.—Lead has its longest line, 4058·0, in the violet; this line alone is visible in the chloride spectrum; 5607·0 in the yellow-green, which appears nearly as long, is not visible.

Baric Chloride, $Ba\ Cl_2$.—Barium has three lines, distinguished by their great length; they are 5534·5 in the yellow-green, 4933·4 in the green, and 4553·4 in the indigo. These only are visible in the chloride spectrum.

Aluminic Chloride, $Al_2\ Cl_6$.—Aluminium has but two long lines, which fall between H_1 and H_2, and are of the following wave-lengths, 3961·0 and 3943·0; these alone are visible in the spectrum of aluminic chloride.

It will be seen from the foregoing that in the case of elements with low atomic weights, combined with one equivalent of chlorine, the number of lines which remain in the chloride is large—over 60 per cent., for instance, in the case of Li, and 40 per cent. in that of Na. While, on the other hand, in the case of elements with greater atomic weights, combined with two equivalents of chlorine, we get a much smaller number of lines remaining—8 per cent., for instance, in the case of Ba, and 3 per cent. in the case of Pb.

Preliminary Experiments with Mechanical Mixtures.

Another series of experiments has had for its object the examination of the spectrum of mechanically mixed metals—alloys prepared *ad hoc*. These experiments, which

at present are preliminary only, were made because it seemed clear that the same law that was observed with the chlorides should hold good.

A cursory examination of the spectra of some amalgams of tin and magnesium has shown that this is the case.

For instance, it is possible to begin with an alloy which shall only give us the longest line or lines in the spectrum of the smallest constituent, and by increasing the quantity of this constituent the other lines can be introduced in the order of their length. This reaction is so delicate that I learnt from it a thing I had not before observed, that the least refrangible line of *b*, the triple line of magnesium, is really a little longer than its more refrangible companion; for the spectrum of magnesium was reduced to this one line in an alloy in which special precautions had been taken to introduce the minimum of magnesium.

It follows from this statement that not only is the spectrum-analysis almost infinitely more delicate than it has hitherto been supposed to be in the case of the elements in which the difference between the longest and shortest lines is least*, but that in time it may become quantitative; for if the admixture of certain other bodies extinguishes the shorter lines of metallic spectra, it would seem that a series of carefully executed maps of the spectra of alloys, the proportions of the constituents of which are known, will place in our hands the means of determining (roughly it is true) by mere inspection the quantity of the sought metal present in an alloy, the composition of which *quâ* that metal is unknown. At the same time it is clear that further progress must be made before such a method can be practically employed in the arts.

Although the working hypothesis which has suggested the various lines of research which have been followed is, I think, sufficiently clear, I refrain from dwelling upon it until other researches now in progress enable me more fully to judge of its value, and to state at greater length the various conclusions which may be drawn from it.

Application of these Observations to the Solar Spectrum.

These observations have an important bearing upon the solar spectrum, for the reason that, as is well known, all the lines known to exist in the spectrum of an element supposed to be present in the sun's atmosphere are not in all cases reversed.

Before I proceed to give the facts in detail it will be well to go over the prior work of KIRCHHOFF and ÅNGSTRÖM, to see precisely the evidence on which our present knowledge of the elements in the solar atmosphere, as determined by KIRCHHOFF's method of solar observation (that is, the non-localization or integration of the various solar regions, such as spots, faculæ and chromosphere), rests.

KIRCHHOFF, in his paper referring to FRAUNHOFER's prior determination of the double line D being coincident with a double line observed in the spectrum of sodium vapour, locates sodium vapour in the solar atmosphere, as Professor STOKES had done before him.

* The great lengths of the lines of sodium, lithium, &c. at once account for the delicacy of their spectrum reactions.

Coincident with all the bright iron lines which he observed with the spark he used (he only saw a small number of the lines), he found well-defined Fraunhofer lines. He therefore located iron vapour in the atmosphere. The rest of the evidence relating to other metals I give from the translation of his memoir by Professor ROSCOE*.

"As soon as the presence of one terrestrial element in the solar atmosphere was thus determined, and thereby the existence of a large number of Fraunhofer lines explained, it seemed reasonable to suppose that other terrestrial bodies occur there, and that, by exerting their absorptive power, they may cause the production of other Fraunhofer lines; for it is very probable that elementary bodies which occur in large quantities on the earth, and are likewise distinguished by special bright lines in their spectra, will, like iron, be visible in the solar atmosphere. This is found to be the case with calcium, magnesium, and sodium. The number of the bright lines in the spectrum of each of these metals is indeed small; but those lines, as well as the dark ones in the solar spectrum with which they coincide, are so uncommonly distinct that the coincidence can be observed with very great accuracy.

"In addition to this, the circumstance that these lines occur in groups renders the observation of the coincidence of these spectra more exact than is the case with those composed of single lines. The lines produced by chromium also form a very characteristic group, which likewise coincides with a remarkable group of Fraunhofer lines; hence I believe that I am justified in affirming the presence of chromium in the solar atmosphere. It appeared of great interest to determine whether the solar atmosphere contains nickel and cobalt, elements which invariably accompany iron in meteoric masses. The spectra of these metals, like that of iron, are distinguished by the large number of their lines; but the lines of nickel, and still more those of cobalt, are much less bright than the iron lines, and I was therefore unable to observe their position with the same accuracy with which I determined the position of the iron lines. All the *brighter lines* of nickel appear to coincide with dark solar lines; the same was observed with respect to some of the cobalt lines†, *but was not seen to be the case with other equally bright lines of this metal.* From my observations I consider that I am entitled to conclude that nickel is visible in the solar atmosphere; I do not, however, yet express an opinion as to the presence of cobalt. Barium, copper, and zinc appear to be present in the solar atmosphere, but only in small quantities; the brightest of the lines of these metals correspond to distinct lines in the solar spectrum, but the weaker lines are not noticeable. The remaining metals which I have examined, viz. gold, silver, mercury, aluminium, cadmium, tin, lead, antimony, arsenic, strontium, and lithium, are, according to my observations, not visible in the solar atmosphere. Through the kindness of M. GRANDEAU, of Paris, I obtained several pieces of fused silicium; I was thus enabled, by using them as electrodes, to examine the spectrum of this element. The lines in the silicium spectrum are, however, with the exception of two broad green bands at 1810 and 1830, so deficient in luminosity that I was unable to

* Transactions of Berlin Academy, 1861. Translated by ROSCOE. Macmillan.

† The italics are mine.

determine their position with sufficient accuracy to reproduce them in my drawing. The two bright green bands do not correspond to dark bands in the solar spectrum; so that, as far as I have been able to determine, silicium is not visible in the solar atmosphere."

It will be seen from the foregoing that KIRCHHOFF dealt mainly with the brightest lines, although the test failed him in the case of cobalt, for a reason I shall show further on. Hence, as a result of KIRCHHOFF'S work, we have in the solar atmosphere:—

Present.	*Doubtful.*	*Absent.*
Sodium.	Cobalt.	Gold.
Iron.		Silver.
Calcium.		Mercury.
Magnesium.		Aluminium.
Nickel.		Cadmium.
Barium.		Tin.
Copper.		Lead.
Zinc.		Antimony.
		Arsenic.
		Strontium.
		Lithium.
		Silicium.

ÅNGSTRÖM* gives no list such as this, but in its place a table of coincidences observed. THALÉN, his associate, in a separate memoir†, gives, however, as present in the sun:—

Sodium,	Chromium,	Hydrogen,
Iron,	Nickel,	Manganese,
Calcium,	Cobalt,	Titanium,
Magnesium,		

thus rejecting zinc and barium from KIRCHHOFF'S list of accepted elements, adding cobalt from the doubtful list, and hydrogen and manganese from ÅNGSTRÖM'S, and titanium from his own observations.

The table of coincidences referred to and ÅNGSTRÖM'S remarks thereon explain the cause of this. KIRCHHOFF'S evidence for zinc had depended upon the coincidence of two lines only, and these were doubtless thought insufficient, as in the cases of the metals retained in the list the number of the coincidences was much greater, viz.:—

Sodium . . .	9 (all)	Magnesium . .	4 (3 ?)
Iron	450	Chromium . .	18
Calcium . . .	75	Nickel . . .	33
Cobalt . . .	19	Hydrogen . .	4 (all)
Manganese . .	57	Titanium . . .	118

* Recherches sur le spectre solaire, par A. J. ÅNGSTRÖM. Spectre normal du Soleil. Berlin, 1869.

† Longueurs d'onde des raies métalliques, p. 11. Nova Acta. Upsala, 1868.

*Barium . . .	11 (of 26)	Zinc	2 ? (of 27)
Aluminium . .	2 ? (of 14)		

From ÅNGSTRÖM'S remarks, which I proceed to give, it is evident that he was not quite satisfied with the brilliancy test relied on by KIRCHHOFF, and that his doubts concerning zinc arose from this cause.

"L'aluminium possède certainement des raies brillantes en plusieurs endroits du spectre, mais les raies situées entre les deux H sont les seuls qui semblent coïncider avec les lignes Fraunhofériennes. Pour expliquer ce phénomène singulier il faut dire que les raies violettes se présentent comme les plus fortes dans le spectre de ce métal. De même que les raies jaunes du sodium, ces deux raies d'aluminium ont fait voir quelquefois le phénomène d'absorption consistant en ce qu'une raie noire se présente dans le milieu de chacune d'elles, ce qui prouve la forte intensité des dites raies. En observant les rayons extra-violettes de ce métal, on décidera si les deux raies mentionnées ci-dessus coïncident ou non avec des raies Fraunhofériennes; car si ma supposition est vraie, les raies extra-violettes doivent coïncider aussi avec les lignes obscures du spectre solaire.

"A deux raies du zinc que j'ai indiquées sur mes planches comme coïncidant avec des raies Fraunhofériennes il en faut ajouter une troisième, située à $4809{\cdot}7$; mais, à l'égard des deux raies, très-larges et très-fortes, d'une apparence nébuleuse, il n'y a pas de correspondance visible; ainsi, la présence du zinc dans le soleil me semble très-douteuse. Je dirai cependant qu'il existe trois raies de magnesium, du même aspect nébuleux, qui ne possèdent pas non plus de correspondance avec les raies de FRAUNHOFER, quoique la présence de ce corps dans le soleil ne permettre pas le moindre doute"†.

In the accompanying maps the lines of certain metallic vapours reversed in the solar spectrum are given under the spectrum mapped by the new method. *It will be seen that invariably the reversed lines are simply those which are longest in the spectrum.*

It is not necessary on the present occasion to dwell upon the great importance of this determination, both in connexion with the fact just stated and the other facts touching the lines which remain longest in chemical combinations‡ and mechanical mixtures. It supplies us at once with the true test to apply to the reversal of solar lines, and a guide of the highest value in spectrum observations of the chromosphere and photosphere. It is one, doubtless, which will shortly enable us to determine the presence of new materials in the solar atmosphere, and it is seen at once that to the last published table of solar elements (that of THALÉN) must be added, zinc, aluminium, and possibly strontium § as a result of the application of the new test.

* I include this "below the line," though I cannot but think that its omission by THALÉN was accidental.

† It will be seen from my maps that this statement is not accurate. THALÉN's later work left only one line doubtful.

‡ A. MITSCHERLICH has noted the disappearance of certain lines in consequence of the presence of several substances in the same flame, but he only applies this to the sun by supposing the substances to be combined and so not to give a spectrum (Ann. de Chim. et de Phys. 3 sér. vol. lxix. p. 176).

§ Barium also, if a *lapsus calami* has not been made.

In the case of the chromosphere, the observation of the order of lengths of the bright lines is invested with a new importance, as also the observation of lines which are not reversed in the ordinary solar spectrum. As an instance of this, I may state that the fact that the re-reversal into brightness in the chromosphere of the line 1474 K is not due to iron vapour, is settled by the other fact, which this new method has enabled me to determine, that the coincident line in the iron spectrum is one of the shortest lines in the whole spectrum.

In the case of the photosphere, not only may we hope to account for such cyclical changes as I have long had reason to suspect and have referred to in prior communications to the Society, but it is essential that spot-spectra shall be photographed with special reference to the consideration that in such spectra the new lines may now be found in all probability, to be those which are only slightly shorter than those ordinarily reversed. This research I am making arrangements to carry on.

It will be observed that in the maps the elements are arranged in the order of their atomic weights. This was done before all the comparisons were made, because, as I have before announced to the Royal Society in the case of several of the elements, the length of the lines in the spectra of the vapours observed in the chromosphere are also most frequently arranged in this order, as predicted by Mr. STONEY*. The comparison rendered possible by the maps also bears out this view with regard to the outer layers; for in the case of H and Na all the lines are reversed; in the case of Mg, about which there was a doubt in ÅNGSTRÖM'S observations, only one line is possibly dropped, and this is not certain. When we come, however, to the elements with higher atomic weights the number of lines reversed is less. But the maps also show that when once the higher layers of the chromosphere, where less constant action goes on, are passed, atomic weight ceases to be a guide, and we are therefore driven to other considerations, which promise to largely increase our knowledge of the kind of action at work in the solar atmosphere and the cyclical variation of that action.

The Maps which accompany this communication have been made by my assistant, Mr. R. J. FRISWELL. They have only been revised by myself. I am anxious to take this opportunity of testifying to the zeal and ability he has displayed in a research necessarily very tedious from its character, and requiring great patience and care.

* This arrangement has since been broken up for the convenience of the engraver. Some of the spectra having both sun and chloride lines had to be displaced by others without these, in order to get the whole of the maps on to the three Plates.

NOTES TO THE MAPS*.

The lengths of the lines are given only in reference to those of the same element; no relation is intended to be indicated between the lines of the various spectra as represented on the Maps. The lengths of the lines of one spectrum as compared with another are liable to great variation—the lines of barium being, for instance, considerably longer than those of zinc, though they are represented as of the same length on the Maps.

The poles were also much further apart in some cases than in others. In the case of barium, for instance, unless the poles were widely separated all the lines would have stretched across the spectrum, while in the case of manganese or nickel, unless the poles were close, no spectrum would be produced. The widths of the winged lines are mere approximations to the relative widths of the lines of the particular spectrum to which they belong, the width of a line in one map only relating to the lines of that map. No comparison can hence be made between widths given in different maps.

Nor must the widths assigned to the lines be regarded as true; they have been purposely exaggerated. For instance, wings of the lines 4924 and 4911 (zinc) cover a length of 8 millims., equivalent on the scale to $\frac{40}{10,000,000}$† millim.; but it is not intended to assert that the wings extend over so large a space.

Plate XI. Strip II.—LITHIUM.

Wave-length.	Length.	Whether reversed in the Solar Spectrum.	Whether in the Spark-Spectrum of the Chloride.	Remarks.
6705·2 6102·0	4 4	Not in Sun.	Present.	These lines invariably stretch across the spectrum when metallic lithium is used as the electrode.
4602·7	1		,,	This line is nebulous but brilliant; it is much shorter than either of the others.

Plate XI. Strip III.—SODIUM.

6160·0 6154·2	3	Reversed.	Not present.	Thalén has represented these lines as extending across the spectrum and longer than 5687·2, 5681·4; but this is not the case.
5895·0 5889·0	4	,,	Present.	The D lines of the solar spectrum; their tops have never been seen, as they invariably stretch from pole to pole.
5687·2 5681·4	3	,,	,,	These lines are slightly longer than those at 6160·0 and 6154·2.
5154·8 5152·5	1	,,	Not present.	These lines are very short and faint.

* Added during the printing of the paper.

† Four one-millionths or forty ten-millionths of a millimetre.

PLATE XI. STRIP III.—SODIUM (continued).

Wave-length.	Length.	Whether reversed in the Solar Spectrum.	Whether in the Spark-Spectrum of the Chloride.	Remarks.
4982·5	1	Reversed.	Not present.	This is really a close pair of lines, represented by THALÉN as a single nebulous line in the map attached to his 'Mémoire sur les longueurs d'onde des raies brillantes des Métaux,' but correctly given by him as double in the maps in ÅNGSTRÖM's memoir on the solar spectrum. The wave-length here given is the mean of the true positions, which are 4983·2 and 4981·9 respectively. The line, though nebulous, is easily divided, and is so represented on the Map.

PLATE XI. STRIP IV.—MAGNESIUM.

5527·4	3	Reversed.	Not present.	
5183·0	4	"	Present.	b_1. This is the longest magnesium line.
5172·0	4	"	"	b_2. This is slightly shorter than b_1.
5166·7	4	"	"	b_3. Slightly shorter than b_2.
4703·5	2	?	Not present.	There is a line coincident with this in KIRCHHOFF's map of the solar spectrum, but it has been dropped out in ÅNGSTRÖM's.
4586·5	......	Reversed.	"	I have never succeeded in observing this line, though very many attempts have been made; it is represented in the solar spectrum by ÅNGSTRÖM as an excessively faint line; and KIRCHHOFF makes it not really coincident but partly overlapping the solar line.
4481·0	1	"	"	This is a very brilliant winged line, but it appears short. THALÉN makes it of the same intensity as the two at 4703·5 and 4586·5; but while this is excessively bright to me, 4703·5 is faint and 4586·5 invisible. KIRCHHOFF represents it in the solar spectrum by a very much broader line than ÅNGSTRÖM does.

PLATE XI. STRIP V.—COBALT.

6142·5	2	Not reversed.	Chloride not observed.	
6121·2	2	"		
6003·5	......	"		This line could not be identified.
5482·4	4	Reversed.		This line is represented in the solar spectrum, but is not named in ÅNGSTRÖM's map.
5452·0	2	Not reversed.		
5443·0	2	"		
5368·0	2	"		
5362·5	2	"		
5359·5	2	"		
5352·4	4	Reversed.		
5351·2	4	"		
5342·6	4	"		
5342·1	4	"		

Plate XI. Strip V.—COBALT (continued).

Wave-length.	Length.	Whether reversed in the Solar Spectrum.	Whether in the Spark-Spectrum of the Chloride.	Remarks.
5279·6	4	Reversed.	Chloride not observed.	
5267·2	4	,,		
5265·8	4	,,		
5234·4	4	,,		
5230·0	2	Not reversed.		This line is slightly shorter than the others to which the number 2 is assigned.
5212·0	3	,,		
4867·0	4	Reversed.		These lines are a little shorter than the others marked 4, and would drop out of the solar spectrum first should a diminution of the thickness of the reversing layer occur.
4839·0	4	,,		
4813·5	2	Not reversed.		
4791·7	4	Reversed.		This line is also a little shorter than the others marked 4. See remarks on 4867·0 and 4839·0 above.
4778·7	4	,,		
4748·5	......	Not reversed.		This line could not be identified.
4580·8	2	,,		This line is coincident with a calcium line, and also with one of iron; in calcium it is long and rather faint (intensity 4, Thalén); in cobalt it is short and faint (intensity 4, Thalén); in iron its intensity is unknown.
4530·5	4	Reversed.		

Plate XII. Strip I.—NICKEL.

6175·7	3	Reversed.	Chloride not observed.	
6115·3	2	,,		
6107·5	2	,,		
5892·0	2	,,		
5856·5	2	,,		
5475·9	4	,,		
5175·6	2	,,		
5168·3	2	,,		
5155·1	2	,,		
5145·7	2	,,		
5142·0	2	,,		
5136·8	2	,,		
5114·9	2	,,		
5099·7	3	,,		
5098·5	3	,,		
5080·6	3	,,		
5079·7	3	,,		
5034·6	2	,,		
5016·5	2	,,		
4983·3	2	,,		
4979·6	2	,,		
4935·1	3	,,		
4917·6	1	Not reversed.		
4903·9	3	Reversed.		
4872·9	1	Not reversed.		
4865·3	2	Reversed.		
4854·7	3	,,		
4830·2	2	,,		
4828·4	2	,,		
4785·8	2	,,		
4755·0	3	,,		
4713·7	4	,,		
4647·0	3	,,		
4401·7	4	,,		

Plate XII. Strip II.—ALUMINIUM.

Wave-length.	Length.	Whether reversed in the Solar Spectrum.	Whether in the Spark-Spectrum of the Chloride.	Remarks.
6371·0	......	Not reversed.	Not present.	Not identified.
6344·5	......	”	”	Not identified.
6244·0	2 }	”	”	Wide and nebulous.
6234·0	2 }			
5722·5	1	”	”	
5695·5	1	”	”	
5592·5	1	”	”	
5056·5	1	”	”	
4662·0	1	”	”	
4529·5	1	”	”	
4511·0	1	”	”	
4478·5	2	”	”	
3961·0	4 }	Reversed.	Present.	These lines appear to be slightly enlarged at the base; but as a wide slit is required to observe them, the widening has not been represented in the Map.
3943·0	4 }			

Plate XII. Strip III.—LEAD.

6656·0	3	Not in sun, according to Ångström's Map.	Not present.	
6452·0	2·5		”	
6059·0	1·5		”	
6040·0	2·5		”	
6009·0	1		”	Winged.
6001·5	2		”	”
5895·0	2		”	
5874·0	1		”	
5856·5	1		”	Winged.
5779·0	1		”	
5607·0	4		Present.	Winged. Next to longest line.
5546·0	3		Not present.	” ” ” ”
5523·5	2		”	
5372·0	3		”	Winged.
5274·5	1		”	
5206·5	1		”	
5201·0	1		”	
5189·0	1		”	
5163·0	1·5		”	Winged; very wide and brilliant.
5045·0	1		”	
5004·5	1		”	
4802·0	0·5		”	
4796·5	0·5		”	
4760·0	0·5		”	
4573·0	?		”	This line is very short, faint, and nebulous. It has been omitted from the Map.
4401·5	0·5		”	Winged; almost concealed by the wings of 4386·5.
4386·5	2 }		”	Winged; very wide and conspicuous.
4246·0	2 }			
4167·5	1		”	Winged; wide.
4062·5	4		”	This line is faint and difficult to observe.
4058·0	4		Present.	Longest line.

Plate XII. Strip IV.—MANGANESE.

Wave-length.	Length.	Whether reversed in the Solar Spectrum.	Whether in the Spark-Spectrum of the Chloride.	Remarks.
6020·7	4	Reversed.	Not observed.	
6015·6	4	"		
6012·5	4	"		
5515·6	4	"		
5443·0	3	Not reversed.		This line has the appearance of being winged more on the less refrangible side than on the other. It falls in a place where there is much glare; and it is probable that a greater dispersive power than was used would break up the supposed wing into lines. It has been accidentally shown as reversed on the Map.
5419·5	4	Reversed.		
5412·4	4	"		
5406·5	4	"		
5399·6	4	"		
5393·5	4	"		
5376·6	4	"		
5359·0	......	Not reversed.		Not seen; could not be found.
5340·2	4	Reversed.		
5254·1	4	"		
5233·6	4	"		
5195·2	4	"		
4822·8	4	"		
4782·6	4	"		
4765·8	4 }	"		Drawn as one line on map, but seen as two.
4764·7	4 }			
4761·5	4 }	"		Drawn as one line on map, but seen as two.
4760·7	4 }			
4753·4	4	"		
4738·0	1	Not reversed.		This line is much shorter than its companions.
4729·0	3	Reversed.		In Ångström's solar spectrum there is a line at 4729·0, but the manganese line beneath is shifted slightly to the left, its position being 4728·9. This is evidently an engraver's error. This line and 4726·0 are represented as one line.
4726·0	?	Not reversed.		
4708·7	4	Reversed.		
4503·5	3			
4501·2	3			
4498·2	3			All these lines appear in close masses, and it has not been possible to represent them on the scale of the map. There are also several discrepancies here between Ångström and Thalén.
4495·2	3			
4491·0	3			
4489·5	3			
4478·9	2			
4472·4	2			
4470·5	2			
4464·0	2			
4461·5	} 3	"		
4461·0				
4459·8	3			
4457·7				
4457·3	} 3			
4457·0				
4456·2				
4455·5	3			
4455·2				
4452·0	?	Not reversed.		This line is not reversed in the sun, but, owing to the closeness of the lines and complication of the spectrum, it was not possible to observe its length. There are 9 lines falling between 4459·8 and 4450·4, and with the dispersion used these lines appear as a mass. The lengths given in the Map, however, represent the contour of the top of the mass, and the line has been brought up to this.

PLATE XII. STRIP IV.—MANGANESE* (continued).

Wave-length.	Length.	Whether reversed in the Solar Spectrum.	Whether in the Spark-Spectrum of the Chloride.	Remarks.
4450·4	3	Reversed.	Not observed.	
4436·4	3	,,		
4435·3	3	,,		
4414·7	3	,,		
4280·5	3	,,		
4265·0	3	,,		
4258·2	3	,,		
4234·8	3	,,		ÅNGSTRÖM represents this line as not absolutely coincident with a solar line which lies close to it. The Mn line is placed at about 4235·0, and the solar line 4234·7; the position given by THALÉN is nearly the mean of these two. From its length we must conclude that it is reversed, and that the slight discrepancies between THALÉN in his metallic spectra and in the map of the solar spectrum appended to ÅNGSTRÖM's memoir is accidental.
4227·0	4	,,		THALÉN makes this very thin; it is, however, bright and strong.
4083·5 } 4083·0 }	3	,,		Seen as one.
4079·6	3	,,		
4062·9	2	,,		
4054·4	2	,,		
4048·1	2	,,		
4040·5	3	,,		
4033·9 } 4032·8 }	3	,,		Seen as one.
4031·7	3	,,		
4029·4	3	,,		
3988·0	3	,,		

PLATE XII. STRIP V.—CADMIUM.

6466·0	1	Not reversed.	Not present.	Winged.
6438·0	2	,,	,,	
6056·5	1	,,	,,	
6003·5	1	,,	,,	
5957·5	1	,,	,,	
5913·0	1	,,	,,	
5790·0	1	,,	,,	
5687·0	1	,,	,,	
5489·0	1	,,	,,	
5471·0	1	,,	,,	
5378·0	3	,, }	,,	These lines are very broad and winged.
5337·5	3	,, }		
5304·5	1	,,	,,	
5153·0	1	,,	,,	
5085·0	4	,, ?	Present. }	Longest lines. The least refrangible is the longest of these three.
4799·0	4	,, ?	,, }	
4676·8	4	,, ?	,, }	
4415·5	3	,,	,,	

* The spectrum of Manganese requires much further investigation. This Table must be regarded as provisional only.

PLATE XIII. STRIP I.—TIN.

Wave-length.	Length.	Whether reversed in the Solar Spectrum.	Whether in the Spark-Spectrum of the Chloride.	Remarks.
6452·0	3	Not in Sun.	Not observed.	Winged.
5893·0	......			THALÉN gives a line here in his map, but not in his list. It could not be identified.
5798·0	3			
5630·0	4			Longest tin line; it is faint, but well defined.
5588·5	3			Winged.
5562·5	3			"
5368·5	1			"
5347·5	1			"
5332·0	3			"
5289·5	1			"
5224·0	2			"
5100·5	2			"
5021·0	1			"
4923·0	1			"
4858·0	2			"
4584·5	1			"
4524·0	4			Next to the longest, well defined and bright.

PLATE XIII. STRIP II.—ZINC.

6362·5	4	Not reversed.	Not present.	This line was in the sun in KIRCHHOFF's time, but has now dropped out; its number on KIRCHHOFF's map is 771·7.
6102·0	1	"	"	Winged.
6022·5	1	"	"	"
5893·5	2	"	"	
5816·0	2	"	"	
5756·0	1	"	"	
5745·0	1	"	"	
5608·0	......	"	"	Not identified.
5577·5	1	"	"	
5563·0	1	"	"	
5465·5	......	"	"	Not identified.
5436·0	1	"	"	
5336·0	1	"	"	
5249·5	1	"	"	
5233·0	1	"	"	
5158·5	1	"	"	
5121·0	1	"	"	
5074·0	1	"	"	
5048·0	1	"	"	
4971·0	1	"	"	
4923·8	3	"	"	} Winged.
4911·2	3	"	"	
4878·0	1	"	"	
4865·0	1	"	"	
4809·7	4	Reversed.	Present.	Longest zinc line.
4721·4	4	"	"	Second longest.
4679·5	4	"	"	Third longest. Same length, apparently, as 6362·5, but it is really longer, for it remains in the sun, while 6362·5 has dropped out since KIRCHHOFF's time.

PLATE XIII. STRIP III.—STRONTIUM.

Wave-length.	Length.	Whether reversed in the Solar Spectrum.	Whether in the Spark-Spectrum of the Chloride.	Remarks.
6550·0	2	Not reversed.	Not present.	
6501·5	2		,,	
6407·0	1		,,	
6387·0	2		,,	
6380·0	2		,,	
5970·5	2		,,	
5850·0	2		,,	
5540·0	2		,,	
5533·5	2		,,	
5522·5	2		,,	
5503·5	2		,,	
5485·0	1		,,	
5480·0	2		,,	
5256·0	1		,,	
5238·5	1		,,	
5228·5	1		,,	
5225·5	1		,,	
5223·5	1		,,	
4967·5	1		,,	
4961·5	1		,,	
4876·0	1		,,	
4872·0	1		,,	
4831·5	1		,,	
4812·0	1		,,	
4783·5	1		,,	
4740·5	1		,,	
4721·0	1		,,	
4607·5	4	?	Present.	This is the very longest Sr line, and in HOFFMANN's continuation of KIRCHHOFF's maps two solar lines fall within the boundary of it, which is wide. One of these now remains, and is the calcium line 4606·5*; the other was probably this Sr line: the numbers in HOFFMANN's continuation are 2386·0 and 2386·4; the position of the centre of the forked extremity of the Sr line would be about 2386·2.
4305·3	2	Not reversed.		
4226·3	3	Coincident with solar Ca line.	,,	Coincident with the longest Ca line; this line probably belongs really to calcium.
4215·3	4	Coincident with solar Ca line.	,,	Coincident with another Ca line whose length is unknown.
4161·0	2	Not reversed.	Not present.	
4078·5	4	?	,,	Not reversed in ÅNGSTRÖM's Map.

* So given in ÅNGSTRÖM's Map, but THALÉN in his list makes the calcium line and that of strontium absolutely coincident at 4607·5.

Plate XIII. Strip IV.—ANTIMONY.

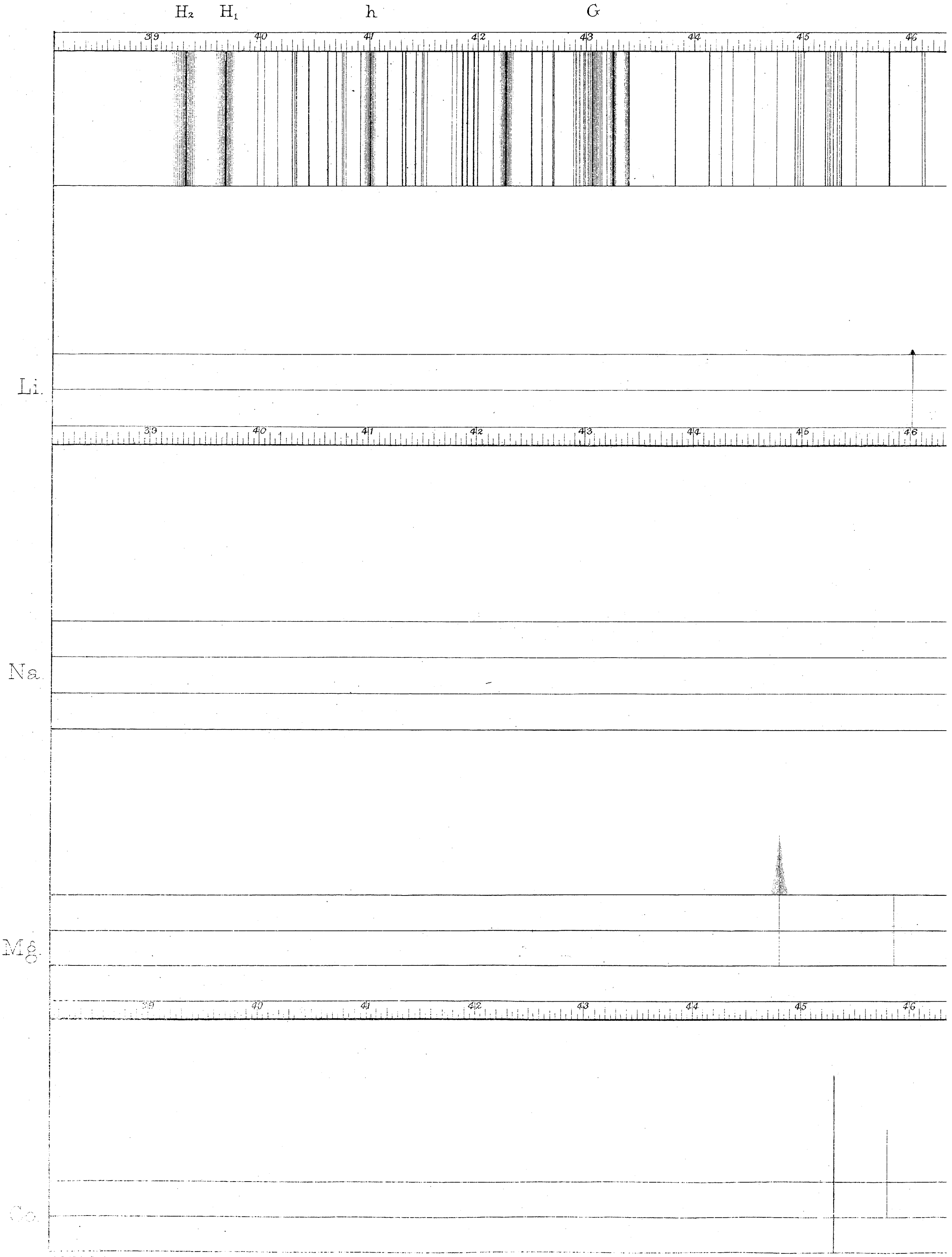
Wave-length.	Length.	Whether reversed in the Solar Spectrum.	Whether in the Spark-Spectrum of the Chloride.	Remarks.
6301·5	1	Not in Sun.	Not observed.	
6244·5	2			
6209·0	2			
6193·0	2			
6155·0	2			
6128·5	4			
6078·0	4			
6051·0	2			
6003·5	4			Winged.
5979·5	2			
5909·0	3			} Winged.
5893·5	3			
5791·5	3			
5638·0	2			
5607·0	2			
5567·0	2			
5463·5	......			} Not identified.
5379·0	......			
5371·5	......			
5352·5	......			
5241·5	......			
5208·0	......			
5177·0	......			
5141·0	2			} Winged.
5112·5	2			
5036·0	2			
4948·5	2			
4877·5	2			
4835·0	2			
4786·0	2			
4734·5	2			
4711·0	2			
4691·0	2			
4591·5	1			} Winged.
4352·0	1			
4265·0	1			Winged ; a little longer than the two preceding lines.

Plate XIII. Strip V.—BARIUM.

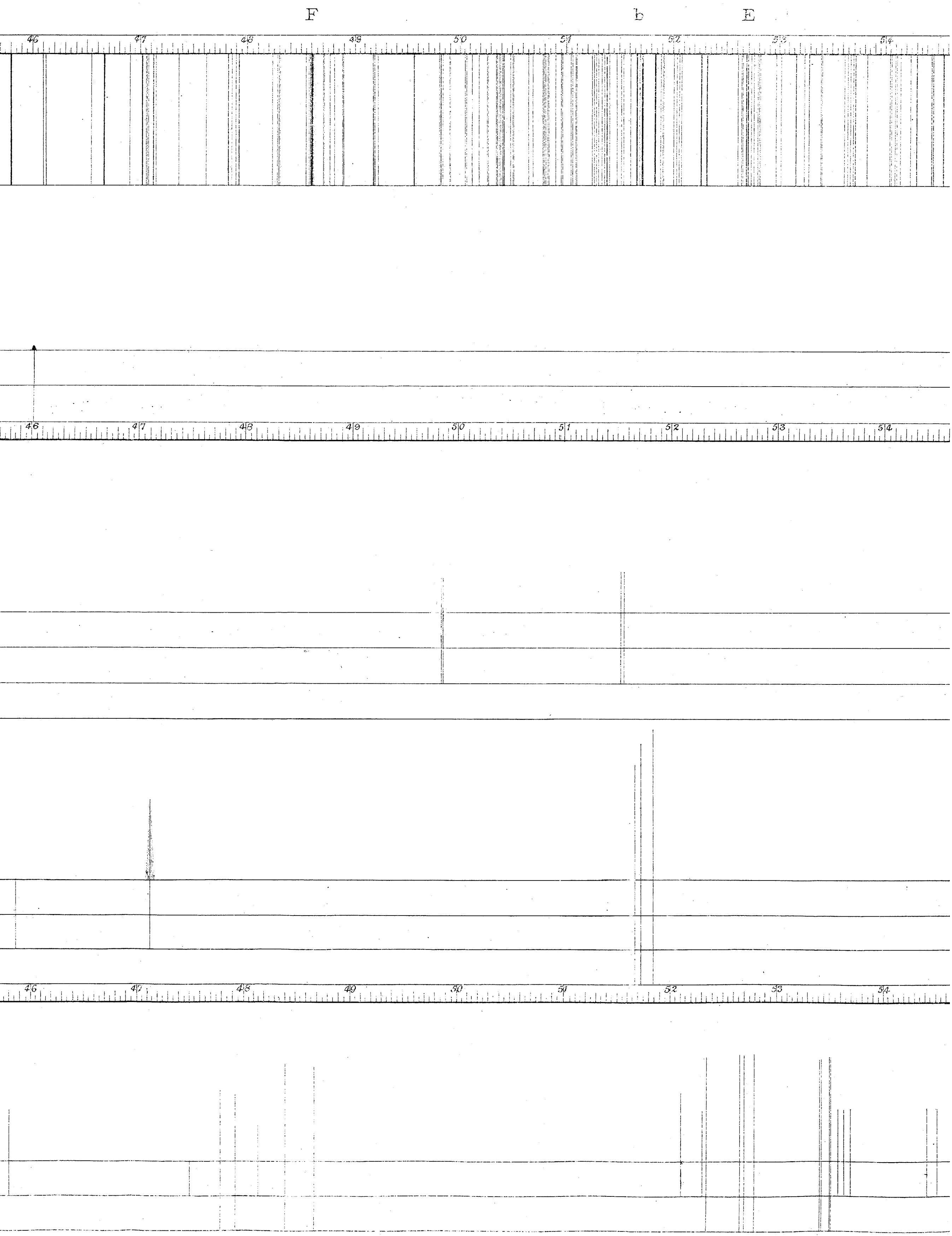
Wave-length.	Length.	Whether reversed in the Solar Spectrum.	Whether in the Spark-Spectrum of the Chloride.	Remarks.
6526·0	1	Not reversed.	Not present.	
6496·0	4	Reversed.	„	
6483·0	3	„	„	Accidentally omitted from solar strip in the Map and made too short.
6449·0	1	?	„	Coincident with a reversed calcium line.
6343·0	1	?	„	There is a line at 6343·2 in Ångström's map, but this is too short for reversal.
6140·6	4	Reversed.	„	
6109·9	3	„	„	
6062·0	1	Not reversed.	„	
6018·0	1	„	„	
5991·5	1	„	„	
5971·0	1	„	„	
5904·5	1	?	„	Coincident with a faint iron line.
5852·5	4	Reversed.	„	
5827·0	1	Not reversed.	„	
5808·5	1 }	?	„	Coincident with two iron lines reversed in the sun.
5803·5	1 }			
5779·5	3	Reversed.	„	
5534·5	4	„	Present.	This appears to be the longest Ba line.
5521·5	3	„	Not present.	
5425·0	3	Not reversed.	„	This line behaves in a very curious manner; it is so nearly of the same height as the one next less refrangible, that it sometimes appears longer and sometimes shorter as the spark flashes, and yet it is not given in Ångström's solar spectrum; it is given reversed in Kirchhoff's solar map, its number being 1371·3.
4933·4	4	Reversed.	Present.	Winged and very brilliant, reverses itself in the spark when the metal is used.
4899·3	4	„	Not present.	Slightly shorter than the preceding one, and winged, but to a less extent.
4553·4	4	„	Present.	Winged.
4524·4	4	„	Not present.	Winged, and slightly shorter than the preceding line.
4165·5	3	Not reversed.	„	Winged.
4130·5	3	„	„	„

Thalén's lines were taken from the spectrum of Ba Cl_2; with a high tension spark the *metal* shows many more lines. The spectrum requires further investigation.

Lockyer.



W. H. Wesley lith.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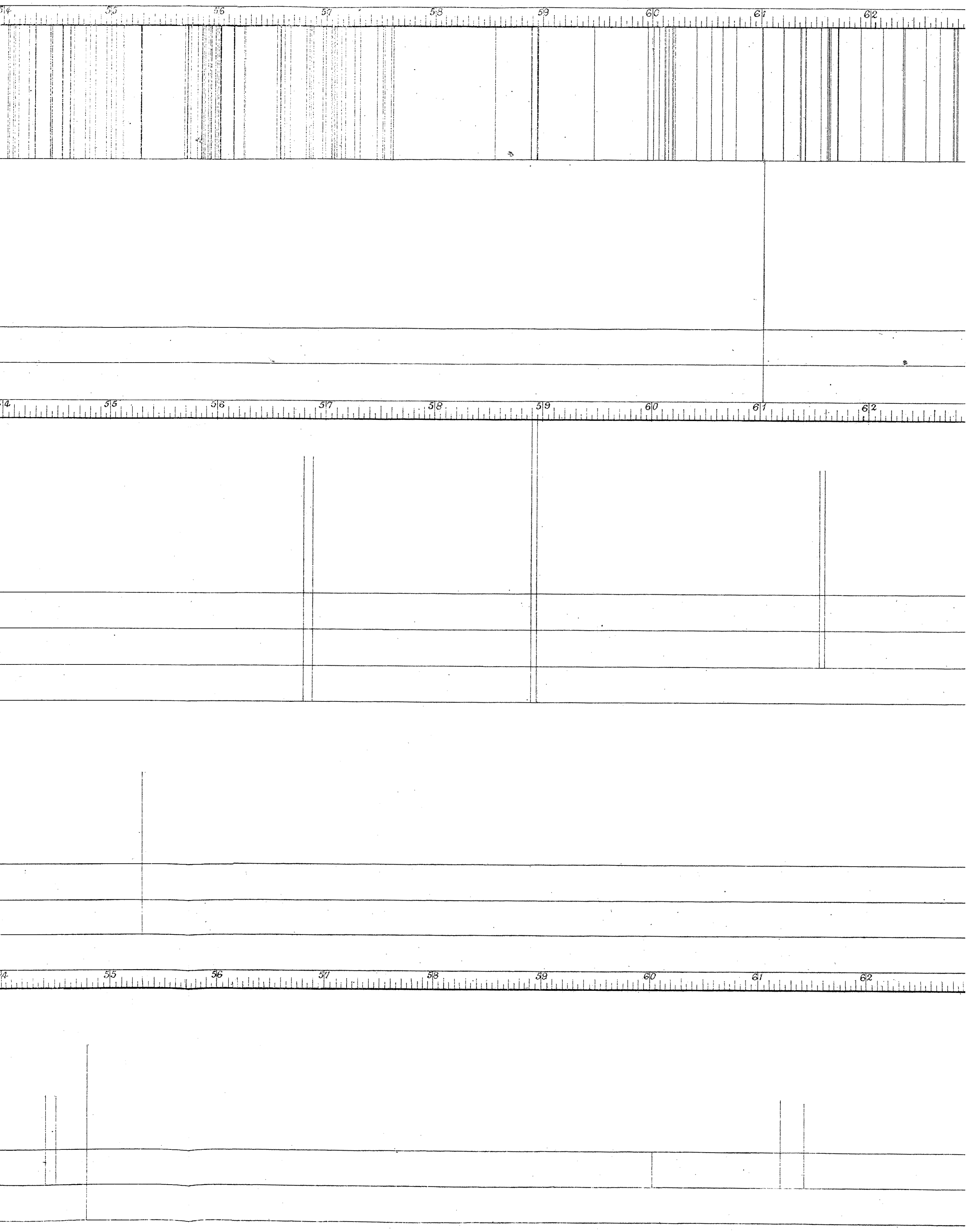
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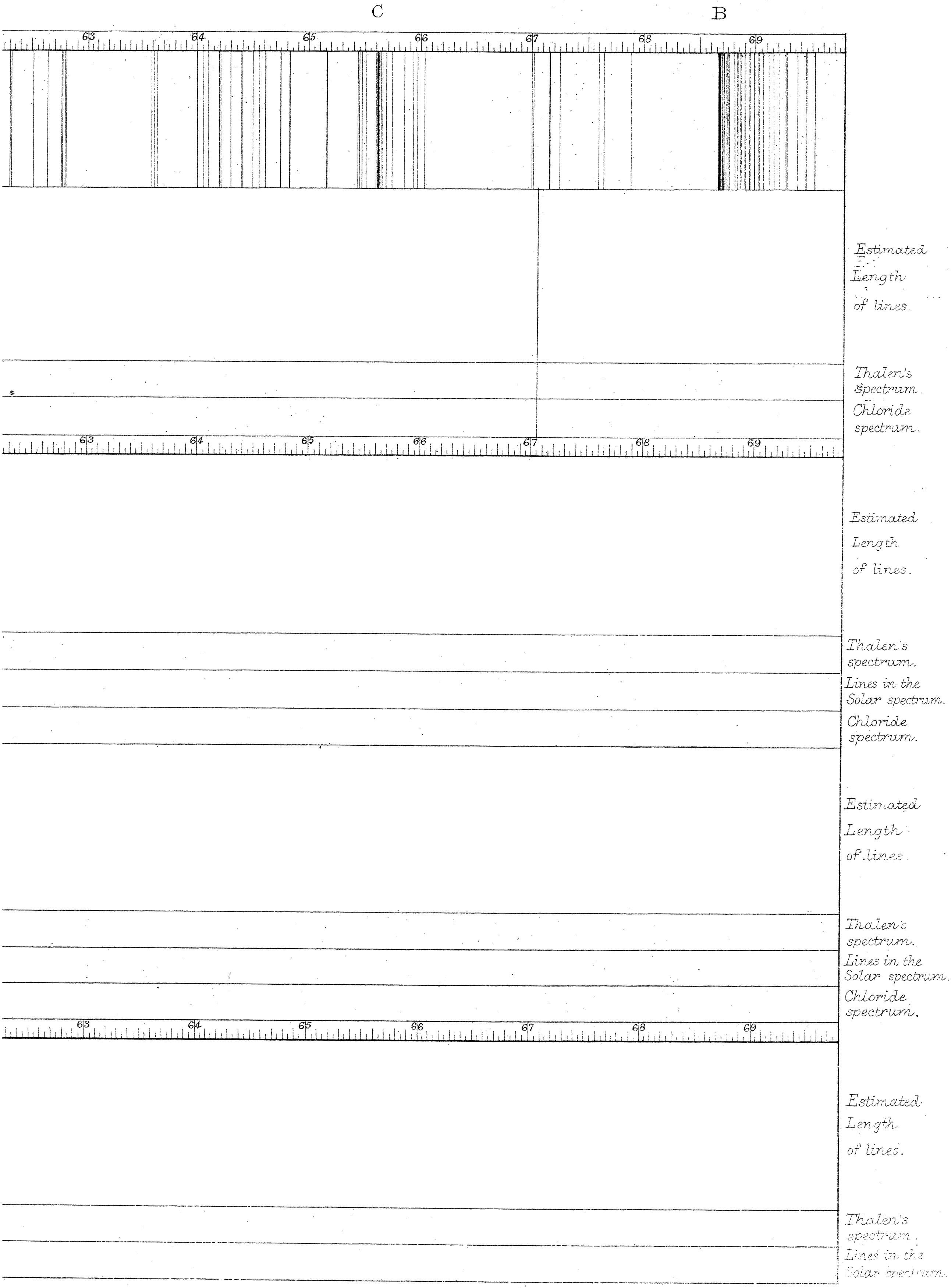
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Estimated Length of lines.
Thalen's Spectrum.
Chloride spectrum.
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Estimated Length of lines.
Thalen's spectrum.
Lines in the Solar spectrum.
Chloride spectrum.
Estimated Length of lines.
Thalen's spectrum.
Lines in the Solar spectrum.
Chloride spectrum.
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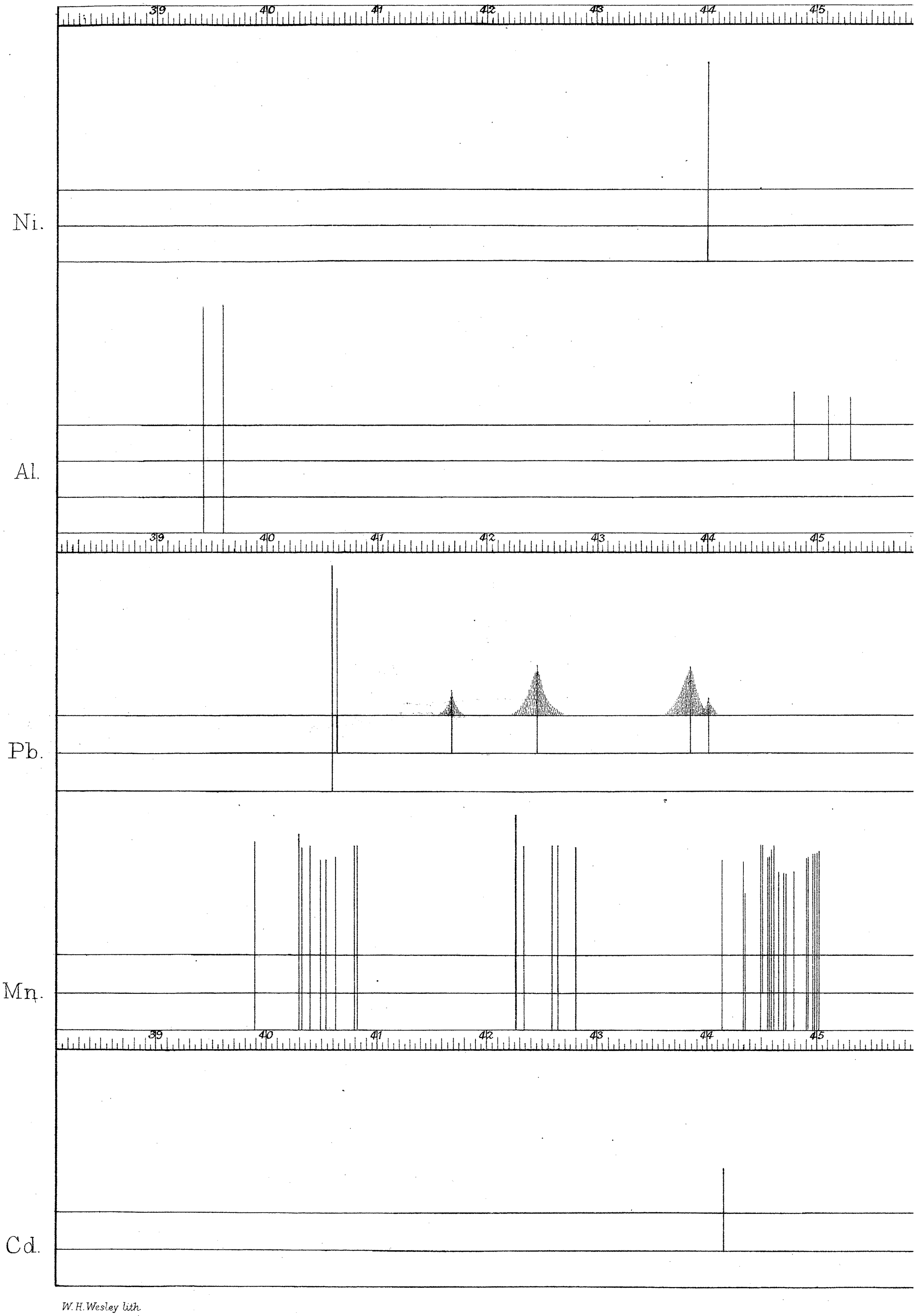
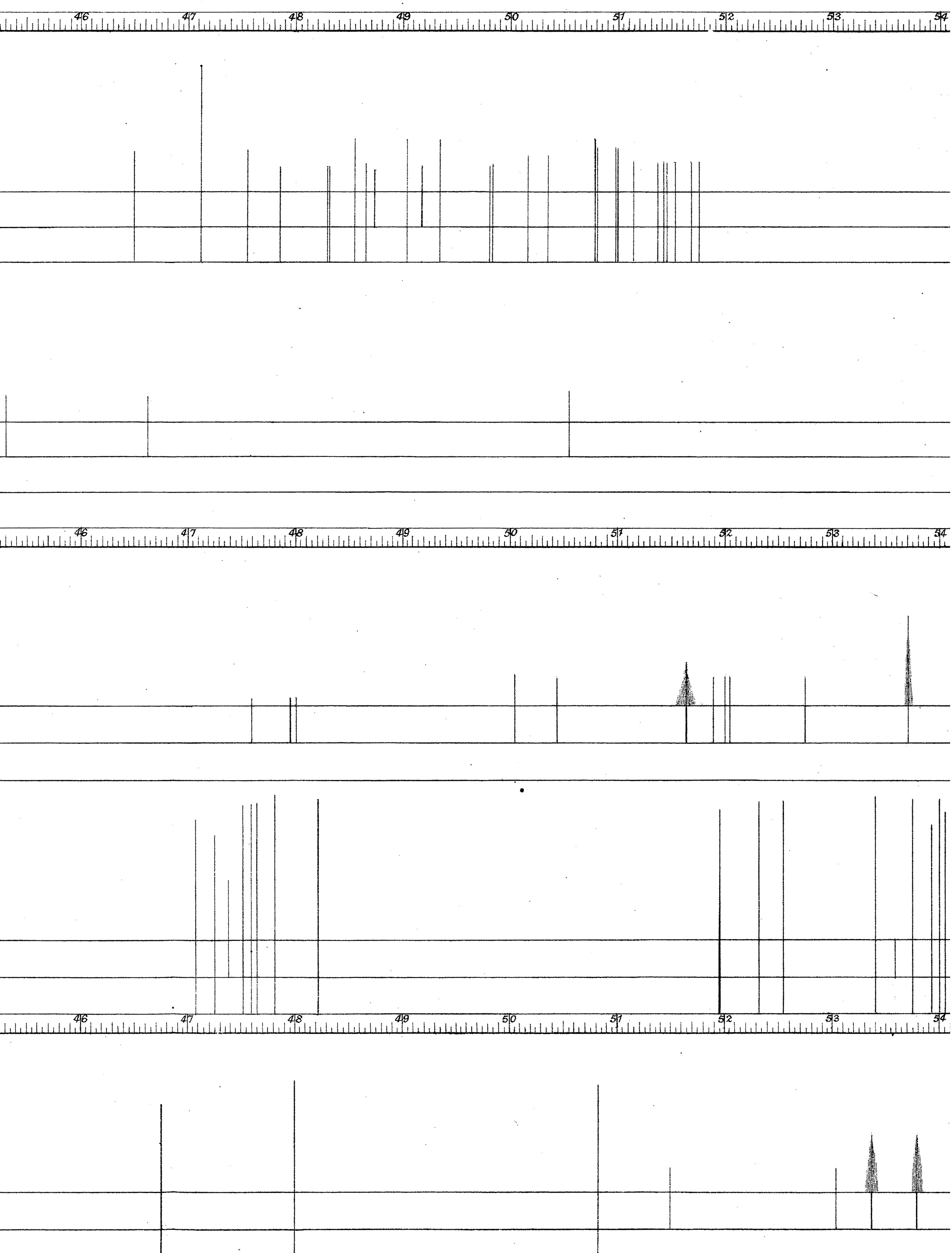
Estimated Length of lines.
Thalen's spectrum.
Lines in the Solar spectrum.

W. West & Co.



W. H. Wesley lith.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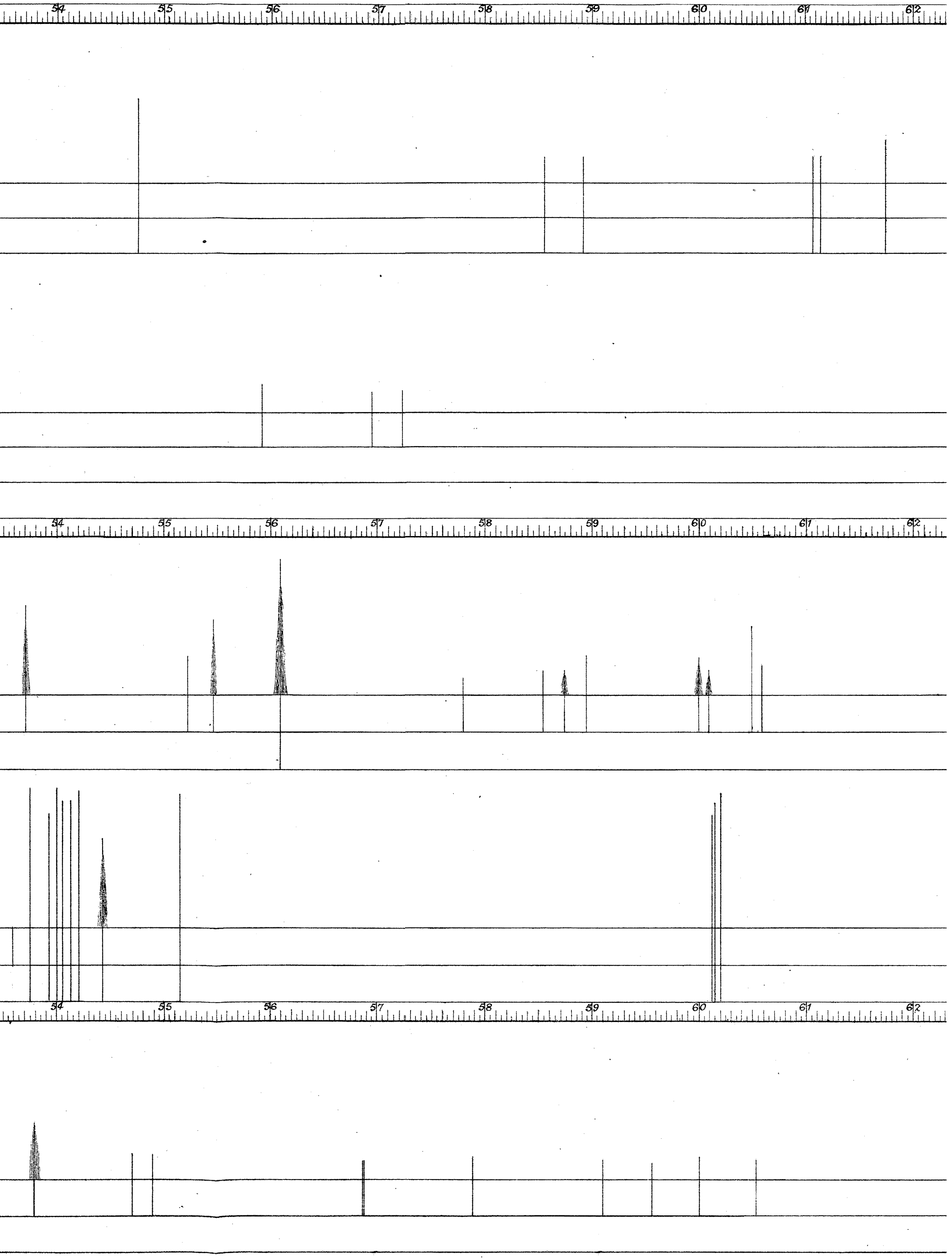
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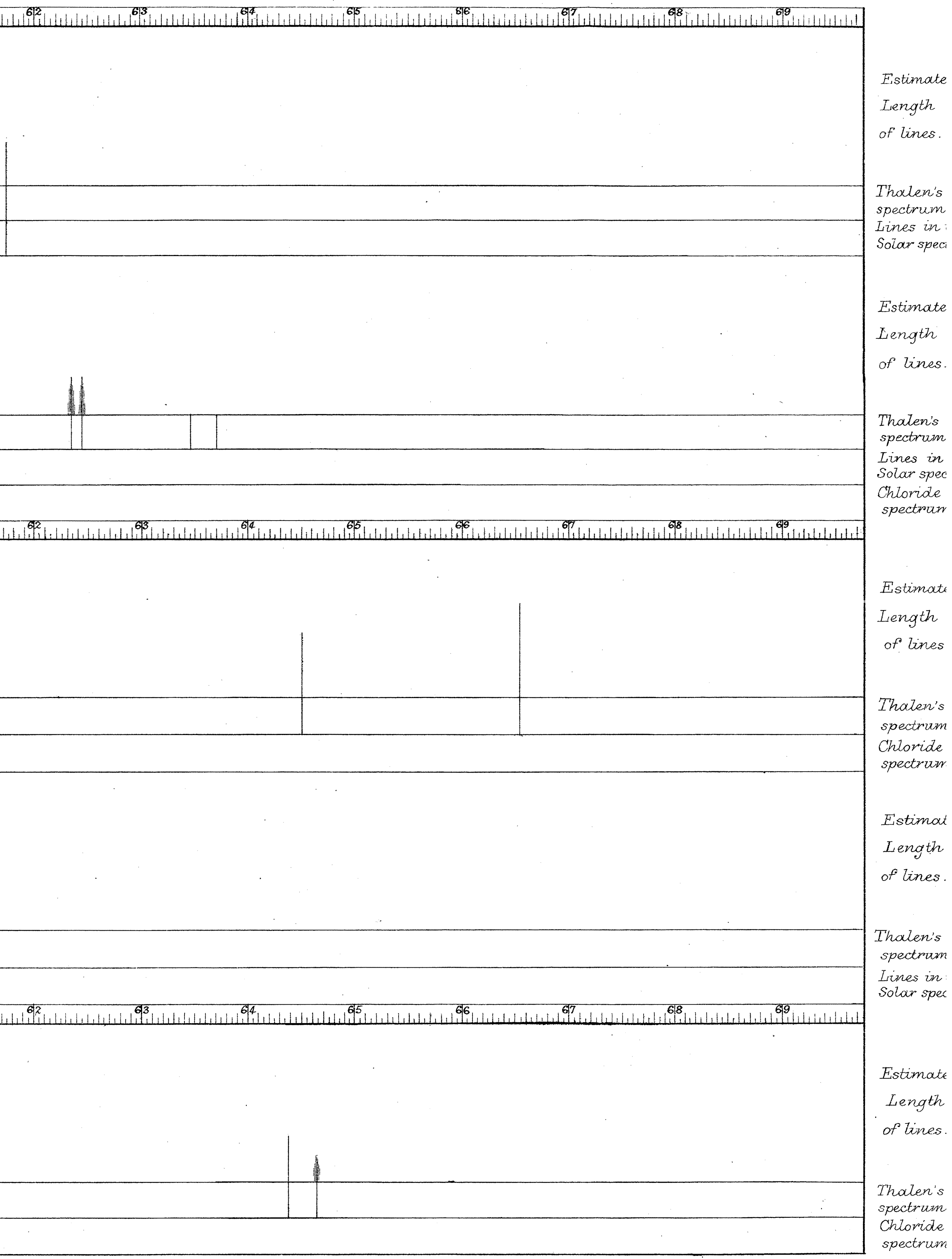
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Estimate
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Thalen's
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spectrum

W. West & C^o. imp.

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Lines in the
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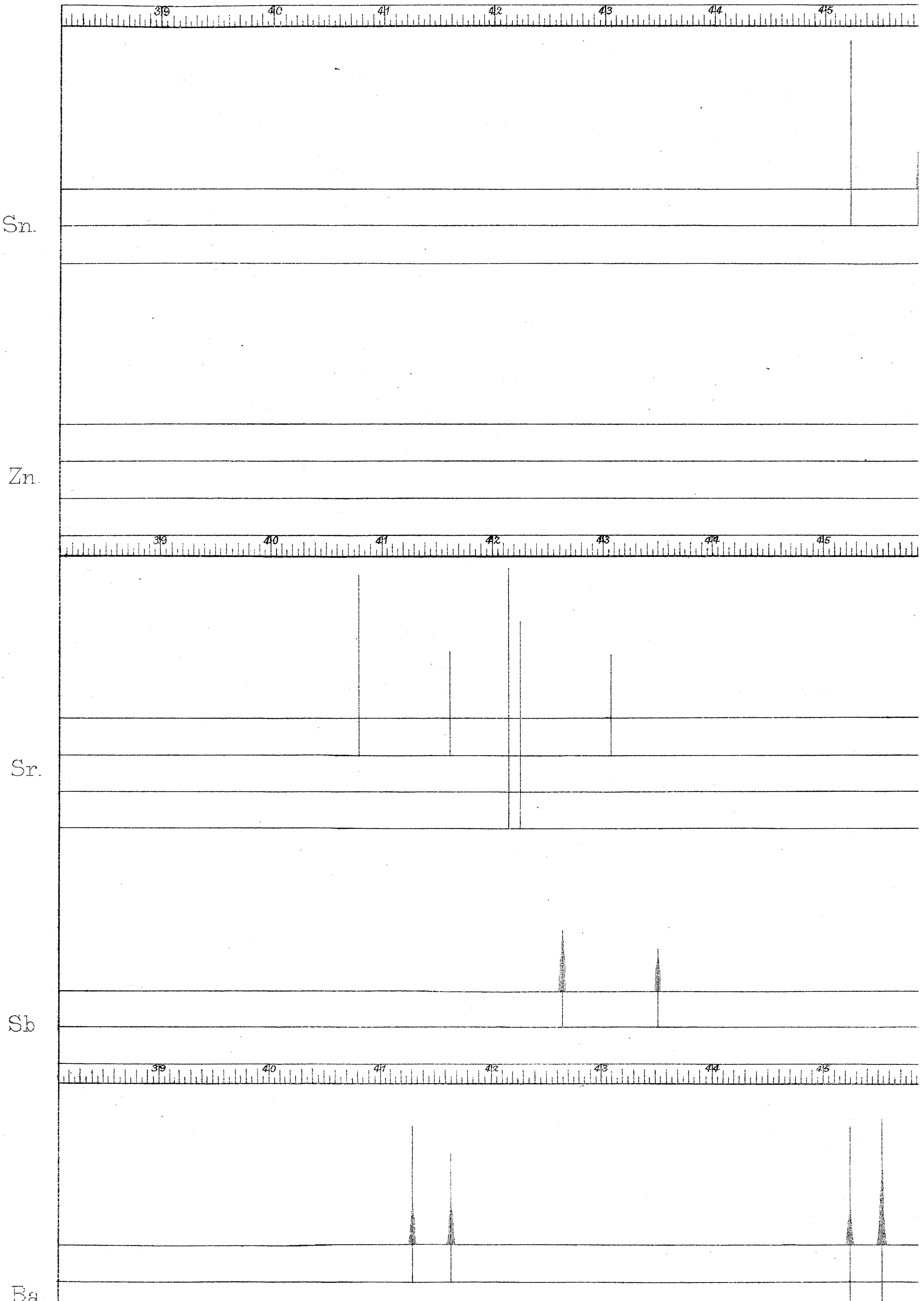
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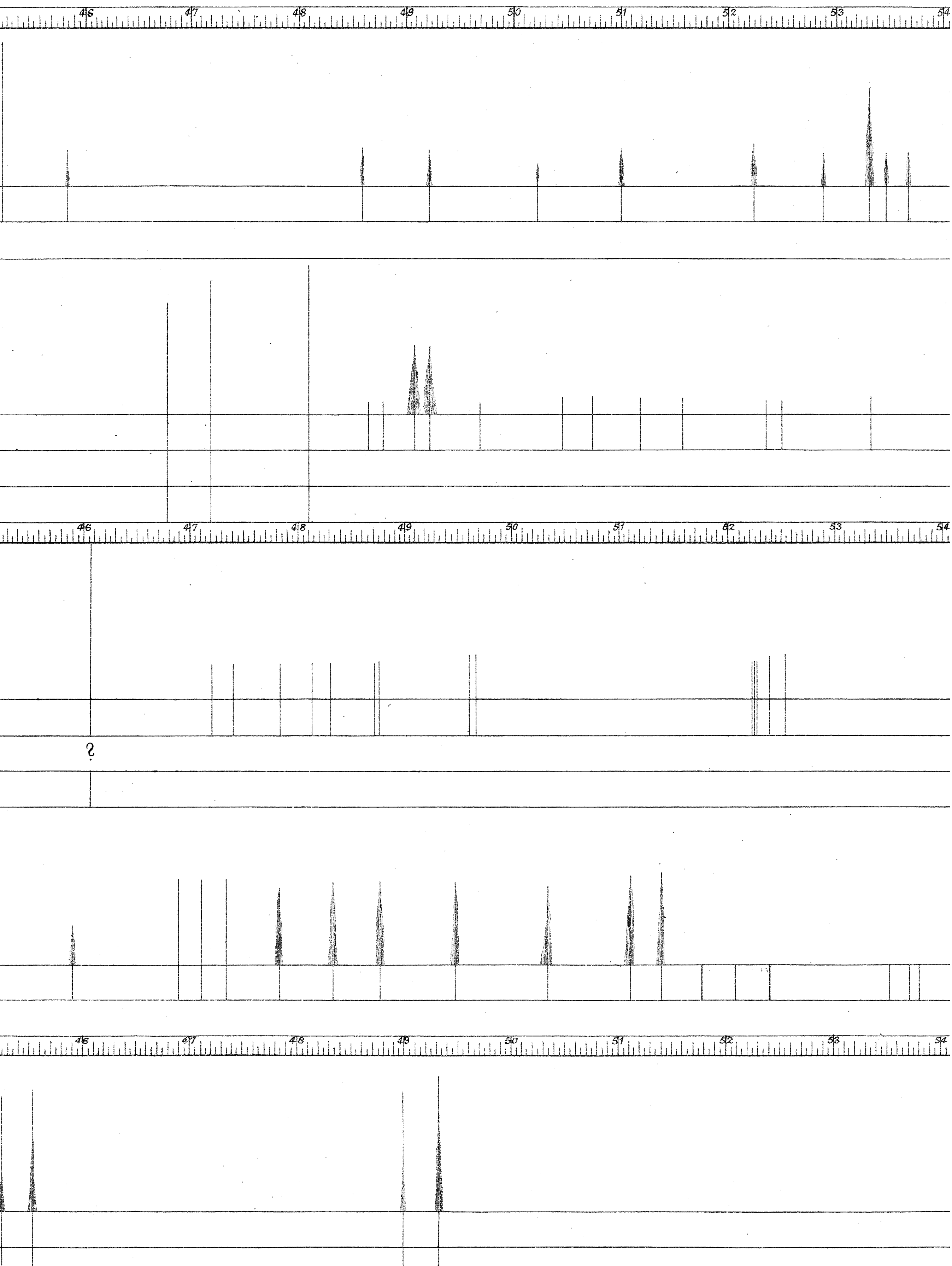
Sn.
Zn.
Sr.
Sb
Ba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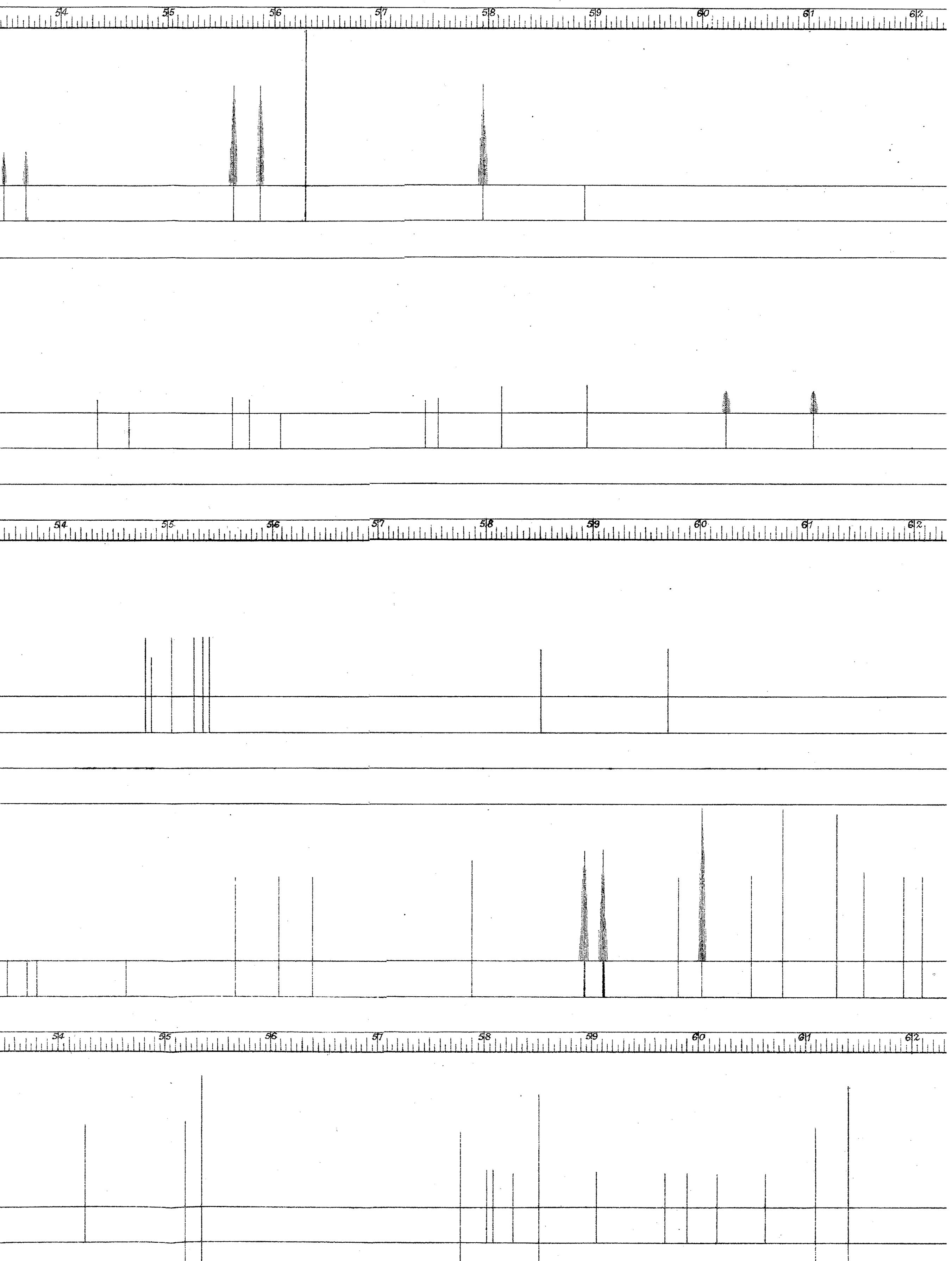
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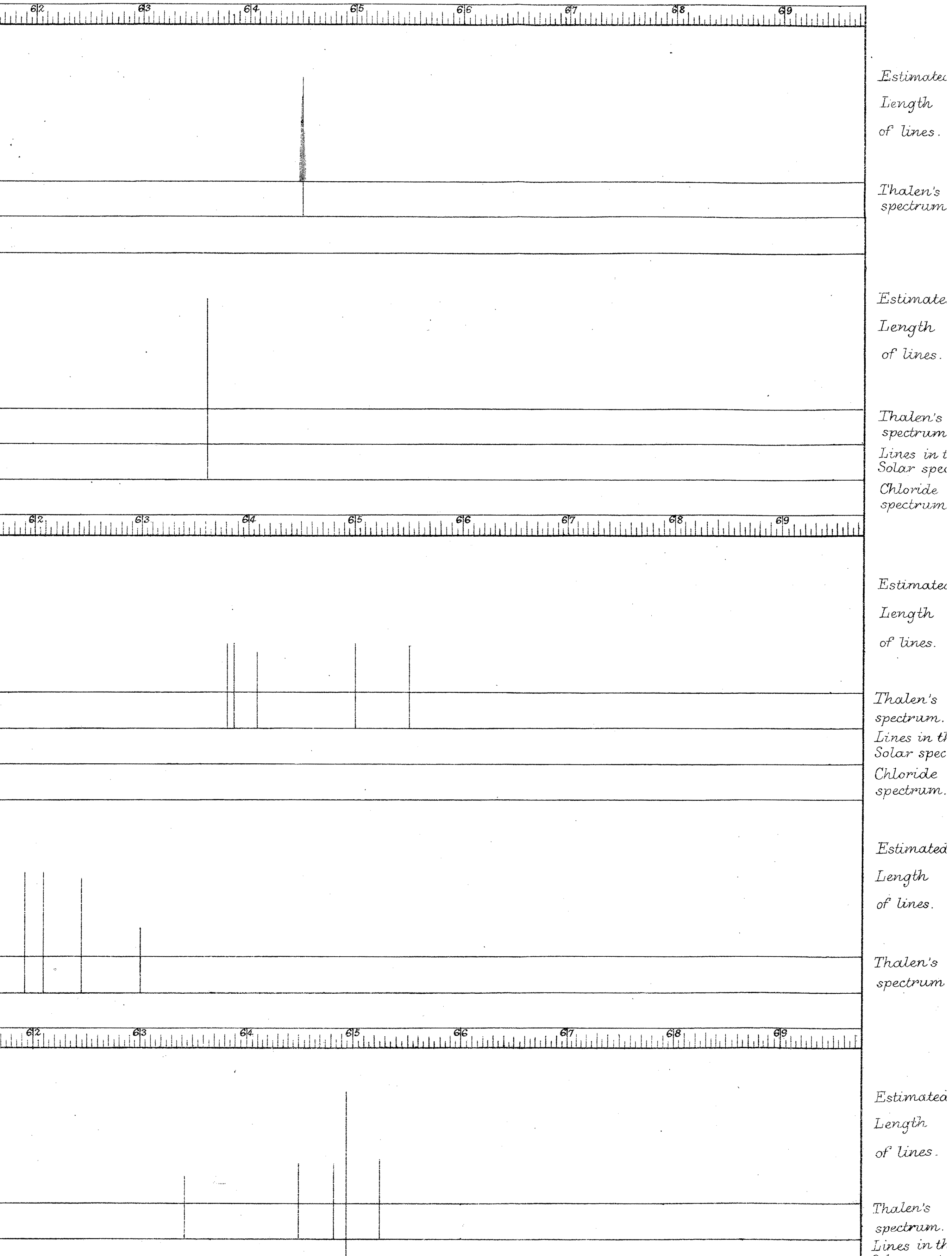
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Chloride
spectrum.

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of lines.

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Lines in the
Solar spectrum.
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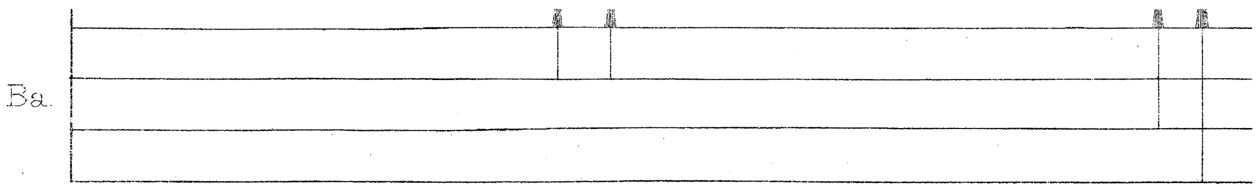
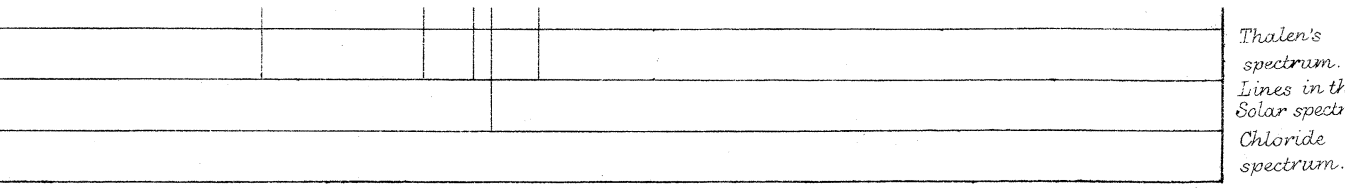


W.H. Wesley lith.


Thalen's spectrum.
Lines in th
Solar spectr
Chloride spectrum.

W. West & C° imp.

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H₂ H₁ h G F b E D C B
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Estimated Length of lines.
Thalén's spectrum.
Chloride spectrum.
Na.
Estimated Length of lines.
Thalén's spectrum.
Lines in the Solar spectrum.
Chloride spectrum.
Mg.
Estimated Length of lines.
Thalén's spectrum.
Lines in the Solar spectrum.
Chloride spectrum.
Estimated Length of lines.
Thalén's spectrum.
Lines in the Solar spectrum.


Ni.
Estimated Length of lines.
Thalen's spectrum.
Lines in the Solar spectrum.
Al.
Estimated Length of lines.
Thalen's spectrum.
Lines in the Solar spectrum.
Chloride spectrum.
Pb.
Estimated Length of lines.
Thalen's spectrum.
Chloride spectrum.
Mn.
Estimated Length of lines.
Thalen's spectrum.
Lines in the Solar spectrum.
Cd.
Estimated Length of lines.
Thalen's spectrum.
Chloride spectrum.


Sn.
Estimated Length of lines.
Thalen's spectrum.
Zn.
Estimated Length of lines.
Thalen's spectrum.
Lines in the Solar spectrum.
Chloride spectrum.
Sr.
Estimated Length of lines.
Thalen's spectrum.
Lines in the Solar spectrum.
Chloride spectrum.
Sb
Estimated Length of lines.
Thalen's spectrum.
Ba.
Estimated Length of lines.
Thalen's spectrum.
Lines in the Solar spectrum.
Chloride spectrum.