II. *On the Spectra of some of the Chemical Elements.*

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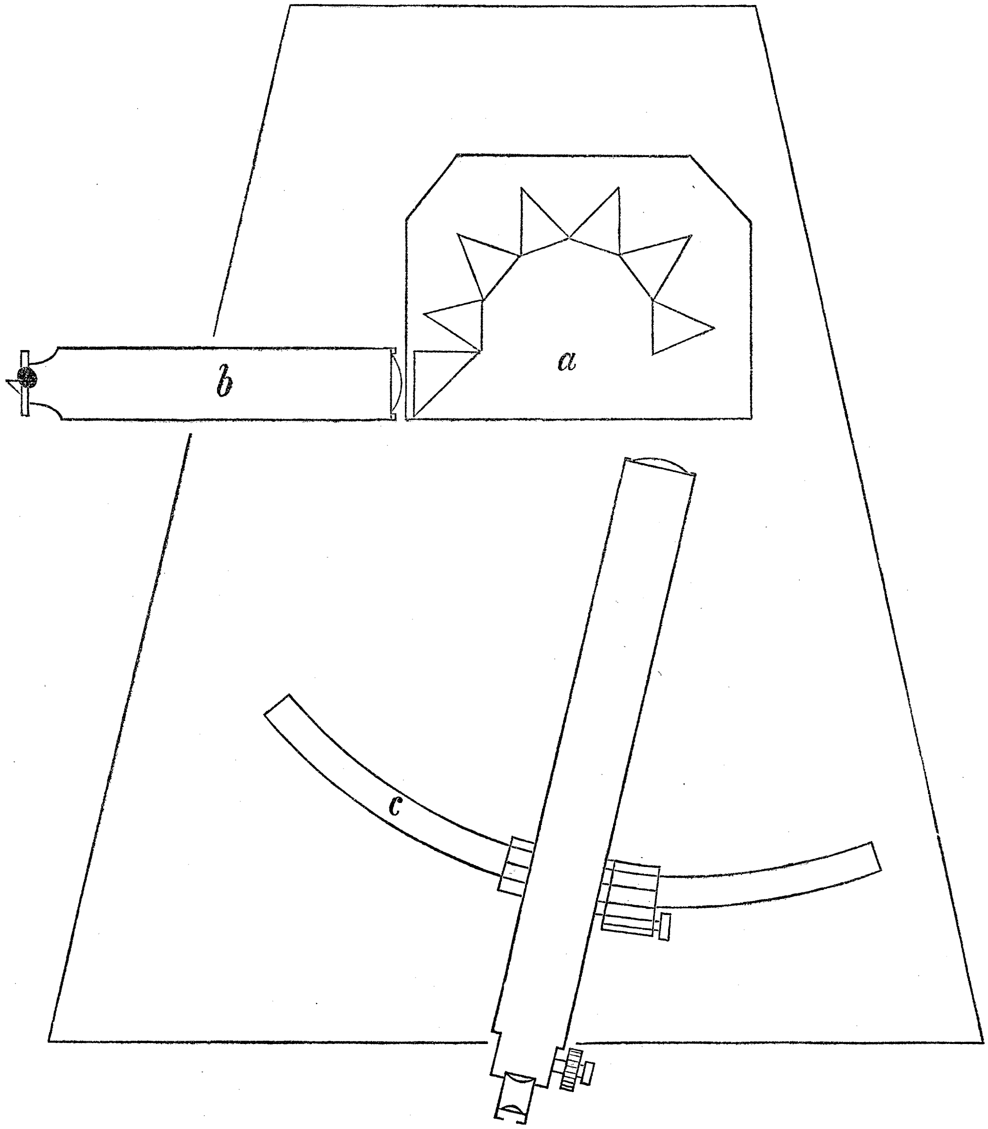
1. I have been engaged for some time, in association with Professor W. A. Miller, in observing the spectra of the fixed stars. For the purpose of accurately determining the position of the stellar lines, and their possible coincidence with some of the bright lines of the terrestrial elements, I constructed an apparatus in which the spectrum of a star can be observed directly with any desired spectrum. To carry out this comparison, we found no maps of the spectra of the chemical elements that were conveniently available. The minutely detailed and most accurate maps and tables of Kirchhoff were confined to a portion of the spectrum, and to some only of the elementary bodies; and in the maps of both the first and the second part of his investigations, the elements which are described are not all given with equal completeness in different parts of the spectrum. But these maps were the less available for our purpose because, since the bright lines of the metals are laid down relatively to the dark lines of the solar spectrum, there is some uncertainty in determining their position at night, and also in circumstances when the solar spectrum cannot be conveniently compared simultaneously with them. Moreover, in consequence of the difference in the dispersive power of prisms, and the uncertainty of their being placed exactly at the same angle relatively to the incident rays, tables of numbers obtained with one instrument are not alone sufficient to determine lines from their position with any other instrument.

It appeared to me that a standard scale of comparison such as was required, and which, unlike the solar spectrum, would be always at hand, is to be found in the lines of the spectrum of common air. Since in this spectrum about a hundred lines are visible in the interval between *a* and H, they are sufficiently numerous to become the fiducial points of a standard scale to which the bright lines of the elements can be referred. The air-spectrum has also the great advantage of being visible, together with the spectra of the bodies under observation, without any increased complication of apparatus.

2. The optical part of the apparatus employed in these observations consists of a spectroscope of six prisms of heavy glass. The prisms were purchased of Mr. Browning, optician, of the Minories, and are similar in size and in quality of glass to those furnished by him with the Gassiot spectroscope. They all have a refracting angle of 45°. They increase in size from the collimator; their faces vary from 1·7 inch by 1·7 inch to 1·7 inch by 2 inches.

The six dispersing prisms and one reflecting prism were carefully levelled, and the former adjusted at the position of minimum deviation for the sodium line D. The train of prisms was then enclosed in a case of mahogany, marked *a* in the diagram, having two openings, one for the rays from the collimator *b*, and the other for their emergence after having been refracted by the prisms. These openings are closed with shutters when the apparatus is not in use. By this arrangement the prisms have not required cleansing from dust, and their adjustments are less liable to derangement. The colli-



mator *b* has an achromatic object-glass by Ross of 1·75 inch diameter, and of 10·5 inches focal length. The object-glass of the telescope, which is of the same diameter, has a focal length of 16·5 inches. The telescope moves along a divided arc of brass, marked in the diagram *c*. The centre of motion of the telescope is nearly under the centre of the last face of the last prism. The eyepiece was removed from the telescope, and the centre of motion was so adjusted that the image of the illuminated lens of the collimator, seen through the train of prisms, remained approximatively concentric with the object-glass of the telescope whilst the latter was moved through an extent of arc equal to the visible spectrum. All the pencils emerging from the last prism, therefore, with the exception of those of the extreme refrangible portion of the spectrum, are received nearly centrically on the object-glass of the telescope. The total deviation of the light in passing through the train of prisms is, for the ray D, about 198°. The interval from A to H corresponds to about 21° 14′ of arc upon the brass scale.

3. The measuring-part of the apparatus consists of an arc of brass, marked *c* in the figure, divided to intervals of 15″. The distance traversed by the telescope in passing from one to the other of the components of the double sodium line D, is measured by five divisions of 15″ each. These are read by a vernier.

Attached to the telescope is a wire micrometer by DOLLOND. This records 60 parts of one revolution of the screw for the interval of the double sodium line. Twelve of these divisions of the micrometer, therefore, are equal to one division of the scale upon the arc of brass. The micrometer has a cross of strong wires placed at an angle of 45° nearly with the lines of the spectrum. The point of intersection of these wires may be brought upon the line to be measured by the micrometer screw, or by a screw attached to the arm carrying the telescope. For the most part the observations were read off from the scale, and the micrometer has been only occasionally employed in the verification of the measures of small intervals. The sexagesimal readings of the scale, giving five divisions to the interval of the double line D, have been reduced to a decimal form, the units of which are intervals of 15″, and these are the numbers given in the Tables. An attempt was made to reduce the measures to the scale of KIRCHHOFF's Tables, but the spectra are not found to be superposable on his. This is due, in great part, probably to the prisms in his observations having been varied in their adjustment for different parts of the spectrum. The eyepieces are of the positive form of construction. One, giving the power of 15, is by DOLLOND; the other, of about 35, is by COOK.

4. The excellent performance of the apparatus is shown by the great distinctness and separation of the finer lines of the solar spectrum. All those mapped by KIRCHHOFF are easily seen, and many others in addition to these. The *whole* spectrum is very distinct. The numerous fine lines between *a* and A are well defined. So also are the groups of lines about and beyond G. H is seen, but with less distinctness.

As, with the exception of the double potassium line near A, no lines have been observed less refrangible than *a*, the Maps and Tables commence with the line *a* of the solar spectrum and extend to H.

The observations are probably a little less accurate and complete near the most refrangible limit. Owing to the feebleness of the illumination of this part of the spectrum, the slit has to be widened, and moreover, the cross wires being seen with difficulty, the bisection of a line exactly is less certain.

5. For all the observations the spark of an induction coil has been employed. This coil has about fifteen miles of secondary wire, and was excited by a battery of GROVE's

construction, sometimes two, at others four cells having been employed. Each of these cells has 33 square inches of acting surface of platinum. With two such cells the induction spark is 3 inches in length. A condenser is connected with the primary circuit, and in the secondary a battery of Leyden jars is introduced. Nine Leyden jars, each surface of each of which exposes 140 square inches of metallic coating, were employed. These are arranged in three batteries of three jars each, and the batteries are connected in polar series.

The metals were held in the usual way with forceps. The nearness of the electrodes to each other, their distance from the slit, and the breadth of the latter were varied to obtain in each case the greatest distinctness. The amount of separation of the electrodes was always such that the metallic lines under observation extended across the spectrum. The two sets of discharging-points were arranged in the circuit in series.

6. Some delay was occasioned by the want of accordance of the earlier measures, though the apparatus had remained in one place and could have suffered no derangement. These differences are supposed to arise from the effect of changes of temperature upon the prisms and other parts of the apparatus. This source of error could not be met by a correction applied to the zero-point of measurement, as the discordances observed corresponded, for the most part, to an irregular shortening and elongation of the whole spectrum.

The principal air lines were measured at one time of observing, during which there was satisfactory evidence that the values of the measures had not sensibly altered; and these numbers have been preserved as the fiducial points of the scale of measures. The lines of the spectra of the metals have been referred to the nearest standard air line, so that only this comparatively small interval has been liable to be affected by differences of temperature. Upon these intervals the effect of such changes of temperature as the apparatus is liable to be subjected to is not, I believe, of sensible amount with the scale of measurement adopted. Ordinarily, for the brighter portion of the spectrum, the width of the slit seldom exceeded $\frac{1}{400}$ inch; when this width had to be increased in consequence of the feebler illumination towards the ends of the spectrum, the measure of the nearest air line as seen in the compound spectrum was again taken, and the places of the lines of the metal under observation were reckoned relatively to this known line.

By this method of frequent reference to the principal air lines the measures are not sensibly affected by the errors which might have been introduced from the shifting of the lines in absolute position in consequence of alterations either in the width of the slit, in the place and direction of the discharge before the slit, or in the apparatus from variations of temperature, flexure or other causes.

The usual place of the electrodes was about ·7 inch from the slit, though occasionally they were brought nearer to the slit. When they are placed in such close proximity, the sparks charge the spectroscope by induction, but the inconvenience of sparks striking from the eyepiece to the observer may be prevented by placing the hand upon the apparatus, or putting the latter into metallic communication with the earth.

The spectrum of comparison was received by reflexion from a prism placed in the usual manner over one-half of the slit. As the spectrum of the discharge between points of platinum, when these are not too close, is, with the exception of two or three easily recognized lines, a pure air-spectrum, this was usually employed as a convenient spectrum of comparison for distinguishing those lines in the compound spectrum which were due to the particular metal employed as electrodes. The measures, however, of all the lines, including those of the air-spectrum itself, were invariably taken from the light received into the instrument directly, and in no case has the position of a line been obtained by measures of it taken in the spectrum of the light reflected into the slit by the prism.

The measures of all the lines were taken more than once; and when any discordance was observed between the different sets, the lines were again observed. The spectra of most of the metals were re-measured at different times of observing. In the measurement of the solar lines for their coordination with the standard air-spectrum, the observations were repeated on several different occasions during the progress of the experiments. The line G of the solar Table is the one so marked by KIRCHHOFF*. When no change in the instrument could be detected, the measures came out very closely accordant, for the most part identical. The discordances due to small alterations in the instrument itself were never greater than 5 or 6 of the units of measurement in the whole arc of 4955 units. As the apparatus remained in one place free from all apparent derangement, these alterations are probably due to changes of temperature. The method employed to eliminate these discordances has been described.

Throughout the whole of the bright portion of the spectrum the probable error of the measures of the narrow and well-defined lines does not, I believe, exceed one unit of the scale.

In the case of lines of sensible breadth and of nebulous bands, the point of intersection of the wires of the micrometer was brought as nearly as possible upon the centre of the lines.

7. It is well known that the lines of different metals as a whole, as well as the lines of the same metal amongst themselves, differ greatly in their characters. For example, the narrow sharply-defined lines of cobalt and iron contrast strikingly with the broader and nebulously edged lines of antimony and arsenic. The spectrum of zinc affords a good example of the differences in this respect between lines of the same metal. In general, it may be that the less volatile a metal is, the narrower and more sharp are the lines, though indeed in the case of the metals barium, calcium, and strontium many of the lines are of hair-like narrowness and sharply defined.

In the spectra of many of the metals bands of light also exist, generally rather broad and faint, which are not resolvable with my instrument into lines. Many of these have the appearance of being true nebulous bands, whilst others under careful scrutiny present indications of being probably composed of lines.

* Untersuchungen ü. d. Sonnenspectrum, 2 Theil, Taf. iii. Berlin, 1863.

These characteristic differences of the lines deserve more careful scrutiny than it was needful, in accordance with my present purpose, to bestow upon them. As approximative indications of their character, the following abbreviations are placed against the numbers in the Tables:—

A line sharply defined at the edges, and narrow when the slit is narrow . . .	s
A band of light, defined *as a line*, but remaining even with a narrow slit, nebulous at the edges	n
A haze of light irresolvable into lines	h
Double, too close for measurement	d

The comparative intensity of the lines is indicated by the smaller figures, which are placed in the position of exponents against the numbers in the Tables. I purposed to limit these estimations to the first ten figures, but so many faint lines were seen that the scale has been extended by adding fractional parts of unity. These figures may be accepted as approximative estimations of the relative intensity of the lines of *each* spectrum. But as the spectra were not, for this purpose, compared one with another, and so many circumstances affect eye-estimations of brightness, these figures must not be taken otherwise than as roughly indicating the values in intensity of the lines of *different* spectra.

In many cases some of the lines of one metal will be seen to be very closely approximated in position to those of another metal, though they do not actually coincide. In the Tables there are lines of different metals having the same numbers, these may with a greater dispersive power be found to be only very near each other. In the case of some, there may be small errors of observation; for to have compared each spectrum with all the others would have involved very great labour.

8. I am indebted to the kindness of Professor W. A. Miller for the loan of specimens of gold, silver, thallium, cadmium, lead, tin, bismuth, antimony, arsenic, and palladium. Dr. Matthiessen has furnished me with lithium, calcium, and strontium* and purified tin, cadmium, lead, bismuth, antimony, and iron. I have procured from Messrs. Johnson and Matthey tellurium, palladium, osmium, rhodium, iridium, and pure platinum.

I have electro-deposited upon platinum, from the solutions of their salts, silver, manganese, chromium, lead, tin, cadmium, cobalt, bismuth, nickel, antimony, and iron. I have also prepared by the voltaic method, amalgams of sodium, potassium, barium, and strontium.

9. *The air-spectrum.*—The lines given in this spectrum are present with all electrodes when the spark is taken in air at the common pressure. To distinguish the lines which belong to air, the spectrum between electrodes of platinum was observed simultaneously with that between points of gold. The lines common to both these spectra were measured as those due to the components of air. The spectrum thus obtained remains invariably

* Dr. Matthiessen informs me that "the calcium, strontium, and lithium were prepared from the pure chlorides as described in the Quart. Journt. Chem. Soc., vol. viii. pp. 107, 143."

constant, with reference to the position and relative characteristics of its lines, with all the metals which have been employed. The air-spectrum *as a whole*, however, varies considerably in intensity and distinctness with electrodes of different metals. As the lines are due to the stratum of air separating the points of the electrodes, it is to be expected that these lines will appear strongest and most distinct when those metals are employed which, being less volatile, will therefore in a less degree displace the air between the electrodes with their own special vapour. This consideration appears to be confirmed by observation. The air-spectrum is especially intense and distinct when the spark is taken between points of platinum, gold, iridium, and rhodium; whilst, of all the metals which I have employed, mercury and sodium, perhaps, are those with which the intensity of the air-spectrum is most diminished. With these comparatively very volatile metals, the air between and about the electrodes must be, to a very considerable extent, replaced by the metals themselves in a state of vapour. It accords with this suggested explanation of the differences in brightness of the air lines with different metals, that, if the electrodes be mercury or sodium and a platinum wire, the air-spectrum is observed to be weaker when the current is so directed that the greater heating effect of the discharge shall be at the mercury or sodium electrode, and to become perceptibly stronger when the current is reversed. It is known that, within certain limits, the air-spectrum is rendered more intense by the separation of the electrodes.

The following experiments have been made to refer the lines of this compound spectrum to the components of common air to which they severally belong:—

a. *Hydrogen.*—The strong line of the air-spectrum at 589·5 is coincident with FRAUNHOFER'S C, and with the red line of hydrogen.

When the spark is taken in air that has passed over sulphuric acid, this line becomes very faint. A larger surface of acid being employed, the line faded out so completely that no trace of it could be perceived. Steam was then mixed with air, when this line became much brighter and the other lines of hydrogen appeared.

The presence and comparative brightness of this line form a delicate test for aqueous vapour.

b. *Carbonic acid.*—Air that had passed through a solution of caustic potash was examined, but its spectrum was not observed to differ from that of ordinary air. When carbonic acid is added to air, several prominent lines make their appearance. These are due to carbon, since they coincide with lines in the spectrum of graphite. One of the strongest and most characteristic of these lines, and a test for carbonic acid, is a red line a little less refrangible than the hydrogen line. Its number is 580·5.

[Though a good indication of the oxygen and nitrogen compounds of carbon, the absence of this line must not always be accepted as a proof that no carbon is present. I have recently found that, when carbon is subjected to the induction spark in the presence of hydrogen, this line in the red is not seen. Further details of these experiments will be given when the spectrum of carbon is described.—February 7, 1864.]

c. *Nitrogen.*—In the spectrum of the electric spark when taken in a current of pure nitrogen, a few of the lines of common air are wanting, but no new lines appear. The lines of the air-spectrum which remain in nitrogen preserve unaltered their relative brightness and their distinctive characters. In the Tables these lines are distinguished by the letter N.

The nitrogen was prepared by causing air freed from carbonic acid by potash, to pass over red-hot finely divided copper which had been previously reduced from the oxide by hydrogen. The nitrogen was then dried by sulphuric acid. The freeness of the nitrogen from oxygen and from moisture was shown by the total extinction of all the lines which did not retain their usual brightness, and the absence of any trace of the strong hydrogen line. Subsequently a fresh portion of nitrogen was prepared by the same method, and a portion of it sealed up at the common pressure in a glass tube of suitable form, pierced with platinum electrodes. This tube continues to give results identical with those obtained in the current of nitrogen.

d. *Oxygen* —When a current of oxygen from fused chlorate of potash was substituted for nitrogen, the numerous lines of the nitrogen spectrum faded out, and those which were extinguished by nitrogen reappeared with an intensity greater than they possess when the spark passes in air. These are distinguished in the Tables with the letter O.

No new lines were added to the spectrum, but an unexpected result was observed. Two (it may be, three) of the lines visible in nitrogen remained also in oxygen. The most noticeable of these is the double line 2642. This in the air-spectrum is not quite so strong as the line next in greater refrangibility. This brighter line became extinct in oxygen at the same time that the double line remained fully as brilliant as in air, if not a little exalted in intensity. This result, therefore, could not be due to any oxygen remaining in the nitrogen, or of nitrogen in the oxygen. The other line, which behaves similarly in oxygen and nitrogen, is the hazy one in the red, 807. The line in the Tables marked with the symbols of nitrogen and oxygen, at 3456, is in the air-spectrum a double line. The narrow defined line of nitrogen is superposed upon the broader nebulous line of oxygen. Oxygen and nitrogen from other sources were then examined. Nitrogen was evolved from a mixture of nitrite of potash and chloride of ammonium. Oxygen was obtained from peroxide of manganese and sulphuric acid, also from bichromate of potash and sulphuric acid, and also from oxide of mercury. The gases thus prepared were identical in their action upon the spectrum with those previously examined. I have not at present carried this inquiry further.

[I have carefully re-examined the lines which are apparently common to nitrogen and to oxygen. I now regard them as due to the superposition in the air-spectrum of lines of oxygen and of nitrogen. When the most remarkable of these, the double line 2642, is closely observed with the eyepiece of a power of 35 times, the double line, as a whole, appears to become in a slight degree more refrangible when the air is replaced by oxygen. As the oxygen lines of the air-spectrum become more brilliant in oxygen, the phenomenon observed may be explained by supposing a pair of unequally bright oxygen lines to be closely approximated in position to, but a little more refrangible than, a similar pair of nitrogen lines.

In air these four lines would form an ill-defined double line, while in oxygen the exaltation in brilliancy of the lines due to oxygen would make up for the extinction of those of nitrogen, thus leaving a pair similar to that seen in air, but now a little more refrangible, from the loss of the less refrangible line of nitrogen, and the greater brightness of the faint and more refrangible of the oxygen lines. This explanation exactly corresponds with the changes in appearance and position of the double line. The observations have been repeated several times with oxygen from chlorate of potash, and also with oxygen from bichromate of potash and sulphuric acid. The change in position as observed relatively to the corresponding air line in the spectrum of comparison was not relied upon. The fixed cross of the micrometer was made to coincide with the oxygen line next in less refrangibility, 2626, the moveable cross was then brought upon the centre of the brighter of the pair 2642. When a current of pure oxygen was made to pass through the glass tube in which the platinum electrodes were sealed, the double line was seen to have moved from the point of intersection of the wires towards the more refrangible end of the spectrum. To restore the cross to a position similar to that which it before occupied, namely, upon the centre nearly of the brighter of the pair of lines, required that the screw should be turned through a part of a revolution corresponding to a little more than two units of the scale. This measure is greater than the *apparent* change in position would have suggested, for in oxygen the lines are rather broader and more nebulous. The distance between the components of the double line is greater in oxygen. The alterations of position and of character are much better seen when the spectra of oxygen and nitrogen are viewed simultaneously.

A similar explanation is to be given of the nebulous band in the red at 807. In oxygen the position of greatest brightness is more refrangible than it is in air and in nitrogen, though the band itself does not advance beyond the more refrangible limit of the corresponding band in air. The line at 629·5 is a pure nitrogen one and fades out completely in oxygen, but then a nebulous line appears at a little distance, about 638. Of this, in the air-spectrum, a faint trace only can be perceived.—Feb. 1864.]

10. *Sodium.*—When the spark was passed between electrodes of sodium, in addition to the well-known double line, three other pairs of lines and a nebulous band made their appearance in the spectrum. The two more prominent of these are not far from air lines, and with an instrument of insufficient dispersive power might easily be confounded with them. As these lines might be occasioned by impurities in the commercial sodium employed, I prepared an amalgam of sodium, by making mercury the negative electrode in a solution of pure chloride of sodium. The mercury had been examined, and its spectrum was known. When the spark passed between this amalgam and a platinum wire, the same lines were seen, with their peculiar characteristics of relative position and intensity. Cotton moistened with solutions of chloride of sodium and of nitrate of soda was then used as one electrode, the other being a platinum wire.

With both these salts the pairs at 820 and 1170 were satisfactorily observed, though it was with some difficulty, and only by occasional glimpses.

I then compared the sodium-spectrum directly with that of the sun. So numerous are the fine lines of the solar spectrum, and so difficult is it to be certain of absolute coincidence, that I hesitate to say more than that the pair of lines 818 and 821 appeared to agree in position with KIRCHHOFF'S lines 864·4 and 867·1; and of the pair 1169 and 1174, one appears to coincide with a line sharply seen in the solar spectrum, but not marked in KIRCHHOFF'S Map, which would be about 1150·2 of his scale, and the other with KIRCHHOFF'S line 1154·2. The other pair and the nebulous band are too faint to admit of satisfactory comparison with solar lines.

11. *Potassium.*—When commercial potassium is employed as an electrode, about 16 lines are seen in addition to the pair near A of the solar spectrum. Four quite distinct specimens of potassium gave identical results, the same lines being visible in all, and no other lines. I then prepared by electricity an amalgam of potassium, but, with the exception of the line 840 occasionally visible, the lines were not seen. As the potassium lines are fainter than those of sodium, this negative result does not appear to be conclusive, since the great intensity of the mercury-spectrum might overpower the feebler lines of potassium, especially when this was present only in small quantity and not in the concentrated metallic form. One electrode was then surrounded with cotton containing concentrated solution of chloride of potassium, and afterwards with cotton containing that of caustic potash. With both these, rather more easily with the latter, the lines 840, 1049, 1065, and 1073 were occasionally and faintly perceived.

[This great diminution in the brilliancy and number of the lines when, in the place of metallic potassium, solutions of its salts are substituted, may be due to the unfavourable condition of the latter for the production of potassium vapour. The large volume of the gases formed by the decomposition of the water must disperse and attenuate the comparatively small volume of vapour of the element forming the base of the salt, and also the great expansion in the gaseous state of the constituents of the water would lower the temperature of the vapour of potassium mingled with them. The salts should be subjected to the discharge free from water, and in a condition in which they conduct the current. If dry, or fused upon the wires, they are disrupted and scattered.

A platinum wire was coiled at one extremity into a little cup-like cage. Chloride of potassium was placed in this and fused. This wire, with the fused bead of chloride, was placed *above* the platinum wire forming the other electrode. A spirit-lamp is placed beneath the wires; as soon as the bead is in a state of fusion, the lamp is withdrawn and contact immediately made. During the few seconds that the chloride remains fused, most of the lines of metallic potassium are seen. Of the lines 1328 and 840 the observation is less certain, and is very doubtful of 763 and of 727.

Protochloride of tin similarly employed gives a brilliant spectrum of tin.—Feb. 1864.]

12. *Calcium.*—The spectrum was obtained from electrodes of metallic calcium, supplied to me by Dr. MATTHIESSEN. The colour of the spark, as seen by the eye, is bril-

liant red purple. The contrast is exceedingly beautiful between this and the intense green light of thallium. Two or three nebulous bands in the red present indications of resolvability. There is also a diffused green light from 1297 to 1375. The line 1506 is in a small degree more refrangible than the strong thallium line. The strong line 1260 is very near a tin line, but the contrast between the sharp calcium line and the nebulous tin line is very marked. A pair of strong lines is seen near the extreme refrangible end of the spectrum, which may coincide with those of FRAUNHOFER'S H. This specimen of calcium produced also the lines of magnesium; these were of course omitted, as on the chemical analysis of this specimen of calcium it was found to contain magnesium.

13. *Barium.*—As I could not obtain barium in the metallic state, I prepared an amalgam of barium by the electrolysis of chloride of barium. The mercury was a portion of the same used in the other experiments, and which had been examined in the spectroscope. The spectrum is one of great beauty, and the lines are for the most part sharp, narrow, and intense. There is a very strong line in the indigo, near a line of platinum; the latter is furnished also by my specimens of iridium and rhodium.

The line next in greater refrangibility appears to agree very nearly in position with one of tin.

14. *Strontium.*—Metallic strontium prepared by Dr. MATTHIESSEN was employed. The spectrum is exceedingly brilliant, the lines being numerous, narrow, and intense. It is remarkable for several bright nebulous columns in the red and orange; these present indications of containing numerous fine lines.

This metallic strontium contains calcium, the lines of which have been eliminated. An amalgam of strontium was prepared, and with this all the principal lines of the spectrum from the metal were confirmed. As might be expected, many of the fainter lines were not recognized in the spectrum of the amalgam.

15. *Manganese.*—The lines were obtained from an electro-deposit of manganese from a solution of the chloride of manganese. Upon comparing this with a specimen of manganese which I was informed had been reduced by charcoal, all the lines of the electro-deposited manganese were seen in the other; but this contained, in addition, the numerous lines of the iron-spectrum. The most characteristic groups are a triple line from 909 to 915·5, the five lines from 2267 to 2401, and the close group extending from 3097 to 3133.

There are two remarkable broad nebulous bands, one at 840 and the other at 1565; the former, I suspect, is double. As the deposited manganese is brittle, the lines were fitful in consequence of the disruption of portions of the deposit by the spark. This may be the reason that some of the finer lines were not observed.

16. *Thallium.*—The specimen of thallium was lent me by Professor W. A. MILLER, who received it as pure thallium from Mr. CROOKES. With the exception of a few faint lines, one in the red rather strong, and a distinct line near the most refrangible end, the spectrum agreed with the description in Professor MILLER'S "Note" on Thallium*.

* Proceedings of the Royal Society, January 1863, vol. xii. p. 407.

17. *Silver.*—The spectrum is that of electrotype silver, obtained from pure nitrate of silver in cyanide of potassium.

18. *Tellurium.*—This metal was supplied to me as pure by Messrs. JOHNSON and MATTHEY. It contains many strong and characteristic lines. The strong line in the red is very near the strong line in cadmium, but the latter is in a small degree less refrangible.

19. *Tin.*—The spectrum was obtained from purified tin, and confirmed by comparison with electrotype tin; one line, not observed in the spectrum of the latter, has been omitted.

20. *Iron.*—Electrotype iron was employed. This spectrum agreed exactly with a specimen received from Dr. MATTHIESSEN as very nearly, if not quite, pure iron.

21. *Cadmium.*—The spectrum of purified cadmium was confirmed by comparison with cadmium electro-deposited.

22. *Antimony.*—The numerous and strong lines of this spectrum are, for the most part, nebulous at their boundaries. The spectrum is that of electro-deposited antimony.

23. *Gold.*—The specimen of which the spectrum is given was received from Professor MILLER. It was reduced by him from the pure chloride, and fused under bisulphate of potash.

24. *Bismuth.*—Electro-deposited from the nitrate of bismuth.

25. *Mercury.*—Commercially pure mercury was washed with nitric acid, and then distilled. A portion of this was placed in a small cup made from glass tube, into which a platinum wire was sealed. The other electrode was a platinum wire.

26. *Cobalt.*—Electrotype cobalt from the chloride was employed. The lines are numerous, sharp, and narrow, and in their groupings there is considerable resemblance to the spectrum of iron.

27. *Arsenic.*—From a specimen of carefully re-sublimed arsenic received from Professor MILLER. The strong line 1814 is very near, but not quite so refrangible as, one of the strong lines of copper. The strong line in the red, 812, is near the hazy band of the air-spectrum.

28. *Lead.*—The lead was obtained by electrolysis from the nitrate of lead.

29. *Zinc.*—Electrotype zinc was used. This spectrum is remarkable for the strong contrast between the nebulous lines, and others near them sharply defined.

30. *Chromium.*—The chromium was electro-deposited. The triple nebulous band from 1081 to 1090 is remarkable. The groups of lines in the blue and indigo, which for the most part fall between air lines, are very beautiful, and in a marked manner characteristic of this metal.

31. *Osmium.*—Received as pure from Messrs. JOHNSON and MATTHEY. Iridium and rhodium have also been measured, but, as these have lines in common, their spectra are deferred.

32. *Palladium.*—A specimen prepared by Dr. WOLLASTON was observed simultaneously with palladium received as pure from Messrs. JOHNSON and MATTHEY. The

latter contained several lines which were not in the Wollaston specimen. The lines only which were common to both spectra were measured, and are given in the Tables.

Nebulous bands, probably resolvable, are seen at 1000, and from 1219 to 1233.

33. *Platinum.*—The lines of platinum are not easily observed, as several of them are fainter than the air lines near which they occur. The points of platinum must be brought near each other. The spectrum was mapped from electrodes of platinum wire specially prepared by Messrs. JOHNSON and MATTHEY as "pure" platinum.

There are two bands of fine lines at 913 and 939.

34. The spectrum of *Lithium* was observed from electrodes of metallic lithium. Only one line of moderate intensity was seen in addition to the three strong lines which are known. The numbers are $521{\cdot}5^6$ s, 856^8 s, 2013^2 s, 2732^5 n.

35. Several other spectra have been measured, or are in progress; these are reserved until the remaining metals and elements, as far as may be practicable, have been investigated.

NOTE TO THE TABLES.

Upon a re-examination of the Tables I found that it frequently occurred that lines of two or more metals were denoted by the same number. It appeared probable that these lines having a common number were not coincident, but only approximated in position within the limits of one unit of the scale employed; and besides, there might be small errors of observation. I therefore selected about fifty of these groups of lines denoted by common numbers, and compared the lines of each group the one with the other, by a simultaneous observation of the different metals to which they belong. Some of the lines were found to be too faint and ill-defined to admit of being more accurately determined in position relatively to each other.

The following lines appear with my instrument to be coincident.

Zn, As 909	Na, Ba 1005	O, As 1737
Na, Pb 1000	Te, N 1366	Cr, N 2336

Of a much larger number of groups, the lines were, by careful scrutiny, observed to differ in position by very small quantities, corresponding for the most part to fractional parts of the unit of measurement adopted in the Tables. These are—

Sn 459	Ba 621·5	Te 657	Bi 837·3	Co 937	Sb 1081	Te 1485	Zn 1797
Sb 458·8	Bi 621	Cd 656	Sb 837	Sb 937·5	Au 1081·5	Fe 1485·3	Pd 1798
Ca 515	Ca 622	Fe 696·2	Cd 889	Au 981	Ca 1256	Tl 1505	Tl 1851
Au 516	Fe 623	Zn 696	Sb 889·5	Sb 981·5	Co 1257	Mn 1505·5	Bi 1851·3
Te 545·5	Au 643	Sb 765	As 908·8	Ca 1031	Fe 1276	Pd 1548	Sb 1900
Sb 545	Ca 642	Te 765·3	Mn 909	Pd 1031·5	Ag 1276·3	Fe 1548·2	Pb 1900·3
	Fe 641·5			Ag 1031·2			N 1900
				Pb 1031·1			
Sn 581	Ca 649	Na 818·3	Ca 921·2	Te 1030·3	Fe 1438	Pb 1593·3	
Bi 581·5	Sn 648	Ca 818	Tl 921		Te 1438·3	Fe 1593	
			Co 921				
			Sb 921·1				

TABLE I.

Solar.	Air.	Na.	K.	Ca.	Ba.	Sr.	Mn.	Tl.	Ag.	Te.	Sn.	Fe.
a 322												
						365^{2} s						
			418^{2} s									
			426^{2} s									
					$441^{\cdot 7}$ s	444^{2} s						
B 449	....	......	......	......	......	......	......	......	......	......	459^{3} s	......
					$486^{\cdot 7}$ s	480^{2} s						
											491^{1} s	......
				$515^{\cdot 7}$ s	$523^{\cdot 7}$ s							
					$532^{\cdot 7}$ s	......	......	......	......	......	......	......
						$549^{\cdot 5}$ s	......	......	......	$545{\cdot}3^{4}$n	......	......
	N $565{\cdot}5^{2}$	......	......	......	......	563^{1} s	......	......	......	......	......	......
					573^{1} s	......	......	......	......	......	581^{1} s	......
C 589·5	H $589{\cdot}5^{4}$ h	......	......	......	......	595^{2} s	......	596^{4} s	......	......	......	......
					608^{1} s							
						619^{2} s	......	......	......	......	......	......
	N $629{\cdot}5^{2}$	......	......	$622^{\cdot 5}$ s	$621{\cdot}5^{7}$ s	......	......	......	......	......	......	623^{1} s
				$625^{1\cdot 5}$ s	......	......	......	......	......	......	......	......
				$637^{\cdot 7}$ s	......	655 h	......	......	......	......	......	$641{\cdot}5^{\cdot 5}$ s
				642^{2} s	645^{1} s	......	......	......	......	......	648^{7} s	$667^{\cdot 5}$ s
				$649^{\cdot 7}$ s	......	......	......	......	......	$657{\cdot}3^{7}$ s	......	......
						669^{4} s	......	......	......	......	......	673^{1} s
			$727^{\cdot 5}$ s	655^{3} s	......	681^{1} s	......	......	......	......	......	$674^{\cdot 5}$ n
				$699^{\cdot 2}$ s	......	684^{1} s	......	......	......	......	......	$683^{\cdot 5}$ s
				$709^{\cdot 2}$ s	704^{1} s	$692^{\cdot 5}$ s	......	......	$690^{\cdot 2}$ s	693^{1} s	......	$696{\cdot}2^{\cdot 5}$ s
			$763^{\cdot 5}$ s	$723^{\cdot 2}$ s	......	$703^{\cdot 2}$ s	$704^{\cdot 2}$ s	......	......	......	......	......
						$705{\cdot}5^{\cdot 5}$ s	......	......	......	$703^{\cdot 5}$ n	......	$709^{\cdot 7}$ s
				813^{1} s	......	723 h	......	......	......	......	......	$719^{\cdot 5}$ s
				818^{4} s	......	$745^{\cdot 2}$ s	......	......	......	735^{2} s	......	$726^{\cdot 5}$ s
	NO 807^{2} h, d	......	......	......	......	760 h	......	......	$762^{\cdot 2}$ s	$765{\cdot}3^{3}$n	......	$758^{\cdot 5}$ s
				843^{3} s	847^{2} s	777 h	......	768^{1} h	......	774^{3} s	......	$763^{\cdot 5}$ s
		$818^{1\cdot 5}$ s	......	......	879^{2} s	$807^{\cdot 5}$ s	837 } h	......	......	......	......	772^{1} s
		821^{1} s	......	$859^{\cdot 2}$ s	......	856^{1} s	843 }	......	......		......	795^{1} s
				$863^{\cdot 2}$ s	......	......	......	......	......	......	......	829^{2} s
			$840^{1\cdot 5}$ s	......	......	......	......	......	......	......	......	$852^{\cdot 5}$ s
				882 h	......	......	......	......	......	894^{2} s	......	$869{\cdot}5^{\cdot 5}$ s
				$921{\cdot}2^{\cdot 2}$ s	......	......	......	......	......	......	......	$909^{\cdot 5}$ s
					$908^{1\cdot 5}$ s	......	$909^{3\cdot 5}$ s	......	$899^{\cdot 5}$ s	917^{1} s	......	$937^{\cdot 5}$ s
	N 959^{1}	......	......	934 h	$925^{1\cdot 5}$ s	924 h	$913^{2\cdot 5}$ s	......	......	$927^{\cdot 5}$ n	......	$953^{\cdot 5}$ s
	N 967^{6}	......	......	......	$943^{1\cdot 5}$ s	941^{1} h	$915^{2}{\cdot}5$ s	921^{2} s	$943^{\cdot 5}$ s	$945{\cdot}3^{6}$ s	......	$995^{\cdot 2}$ s
	N 975^{4}	......	......	......	$993^{\cdot 5}$ s	945^{3} s	......	......	......	$971^{1}{\cdot}5$ s	......	......
	N 978^{1}	......	......	......	......	......	......	960^{6} s	......	......	......	......
D^{1} 1000	....	1000^{8} s	......	......	......	......	......	......	......	......	......	......
D^{2} 1005	....	1005^{8} s	......	......	1005^{1} n	......	......	......	......	......	......	......
Solar.	Air.	Na.	K.	Ca.	Ba.	Sr.	Mn.	Tl.	Ag.	Te.	Sn.	Fe.

From *a* to D.

Cd.	Sb.	Au.	Bi.	Hg.	Co.	As.	Pb.	Zn.	Cr.	Os.	Pd.	Pt.
	396^{3} n											
......	$458{\cdot}5^{1}$ n											
......	475^{3} s	......	473^{4} s									
502^{4} s	487^{3} s	......	......	......	......	......	480^{3} s					
......	$501^{\cdot 5}$ n											
......	......	$516^{\cdot 5}$ s										
.....	517^{1} s	......	......	......	......	......	$542{\cdot}5^{7}$ s					
......	......	$535^{\cdot 5}$ s										
......	545^{1} n	$541^{\cdot 5}$ s	572^{3} s	......	......	......	......	......	541^{1} s			
......	614^{1} n	......	$581{\cdot}5^{1}$ h	......	......	......	......	$577^{\cdot 5}$ n				
......	620^{1} n											
639^{2} n	......	......	621^{4} s	......	645^{1} n, d	......	......	......	$621^{\cdot 5}$ n			
......	640^{1} n											
656^{8} s	......	$643^{\cdot 5}$ s	......	......	......	......	......	696^{7} s	$640^{\cdot 5}$ n	641^{1} s		
......	......	......	......	......	......	672^{1} n						
......	......	$659^{\cdot 5}$ s	......	......	......	......	......	......	654^{1} n			
......	679^{2} h	......	......	685^{1} n	$701^{\cdot 5}$ s							
......	......	......	......	......	......	707^{1} n	......	......	......	......	$685^{\cdot 5}$ s	
......	......	......	......	697^{1} n	$731^{\cdot 2}$ s	......	......	......	......	......	......	$689^{\cdot 5}$ s
......	......	......	......	......	......	759^{1} n						
......	719^{1} n	......	......	......	$745^{\cdot 5}$ s	......	......	782^{1} s	......	$741^{\cdot 7}$ s		
......	729^{2} n	$727^{\cdot 5}$ s	......	......	......	......	......	......	......	......	$762^{\cdot 2}$ s	
......	739^{2} n	$734^{\cdot 5}$ s	......	......	$763^{\cdot 2}$ s							
......	765^{3} n	......	......	......	......	812^{6} n	898^{1} s	......	817^{1} n			
......	......	747^{3} s	......	826^{7} n	844 h	833^{1} n	......	855^{5} n	......	......	$837^{\cdot 2}$ s	
......	787^{1} h	......	$837{\cdot}3^{5}$ n	......	......	850^{3} n	......	......	$843^{1\cdot 5}$ n			
......	$796^{\cdot 5}$ h	......	884^{5} n	$863^{\cdot 2}$ n	$865^{\cdot 7}$ s							
......	819^{2} n	......	......	......	$891^{\cdot 7}$ s	870^{2} n	......	......	$856^{\cdot 7}$ n			
$889{\cdot}5^{\cdot 5}$ n	837^{7} n	......	$887^{\cdot 5}$ s	......	......	......	......	895^{1} s				
918^{1} n	871^{7} n											
953^{1} s	889^{3} n	......	899^{1} s	......	......	$908{\cdot}8^{3}$ n	......	909^{5} n	......	......	......	913 h
986^{1} s	$921{\cdot}1^{8}$ n	$951^{\cdot 5}$ s	939^{1} h	......	921^{1} s	......	924^{2} n					
......	$937{\cdot}5^{2}$ n	$956^{\cdot 5}$ s	943^{1} h	......	$923^{\cdot 2}$ s	......	......	......	......	$929^{\cdot 7}$ s		
......	$981{\cdot}5^{1}$ n	$981^{\cdot 7}$ s	......	......	$931^{\cdot 5}$ s	......	......	......	......	......	......	939 h
......	$988{\cdot}5^{3}$ n	......	......	......	$937^{\cdot 5}$ s	......	......	......	......	......	......	$950^{\cdot 5}$ s
......	......	......	......	......	985^{2} s	......	......	......	......	......	995 }	$958^{\cdot 5}$ s
......	$1000{\cdot}5^{3}$ n	......	......	......	......	......	1000^{1} n	1001^{2} s			} h	
											1005 }	
Cd.	Sb.	Au.	Bi.	Hg.	Co.	As	Pb.	Zn.	Cr.	Os.	Pd.	Pt.

TABLE II.

Solar.	Air.	Na.	K.	Ca.	Ba.	Sr.	Mn.	Tl.	Ag.	Te.	Sn.	Fe.
D^2 1005												
												$1011^{.2}$ s
				$1031^{3.5}$ s	......	......	......	......	......	......	......	......
			1049^{1} n	......	1034^{6} s	......	......	1055^{2} s	$1031{\cdot}2^{.2}$ s	$1030{\cdot}3^{.5}$ s	......	$1030^{.2}$ s
			$1065^{.5}$ n	......	1057^{1} s	$1061^{.5}$ s	......	......	......	1035^{2} s	......	......
			$1073^{1.5}$ n	......	1096^{1} s	......	......	......	......	......	......	$1090^{.5}$ s
	N $1100^{.5}$	......	......	......	......	......	......	$1099^{.5}$ n	......	......	1076^{10} n	......
	N 1118^{1}	......	......	......	......	$1102^{.5}$ n	......	......	......	1111^{7} n	......	......
	N $1135^{.2}$	1169^{2} s	......	......	1119^{1} s	......	......	......	......	1122^{1} s	......	......
	N 1150^{2}	1174^{1} s	......	......	......	......	......	......	......	......	......	......
	N 1171^{1}	......	......	......	......	......	......	......	......	1151^{7} n	......	......
	N 1177^{8}	......	......	......	......	......	......	......	......	......	......	......
	N 1180^{1}	......	......	......	......	......	......	......	......	......	......	......
	N 1187^{7}	......	......	......	......	......	......	......	......	......	......	$1225^{.5}$ s
										......	......	......
										1204^{6} n	......	$1236^{1.5}$ s
	N $1294^{.5}$	......	......	......	......	1203^{1} n	......	......	$1207^{.5}$ n	......	......	$1247^{.5}$ s
	N $1302^{.5}$	......	......	$1247^{.5}$ s	......	......	......	......	......	......	1219^{2} s	$1251^{.2}$ s
	N $1310^{1.5}$	......	......	$1249^{.5}$ s	......	$1227^{1.5}$ s,t	......	......	$1223^{.2}$ n	......	......	1261^{2} s
	N $1314{\cdot}5^{.5}$	......	......	$1252^{1.5}$ s	......	......	......	......	$1227^{.7}$ n	1230^{1} s	......	$1274^{.7}$ s
	N $1319^{.2}$	......	......	$1256^{2.5}$ s	......	......	......	......	$1240^{.3}$ s	......	1260^{8} n	$1276^{.2}$ s
	N $1349^{1.2}$	......	......	$1258{\cdot}5^{.5}$ s	......	$1268^{.2}$ s	1289^{1} s	......	$1257^{.7}$ s	1270^{4} s	......	$1338^{.7}$ s, d
				$1260^{.4}$ s	......	......	......	......	$1276{\cdot}3^{.5}$ s	......	......	$1383^{.5}$ s
	N 1366^{1}	......	......	$1265^{.7}$ s	......	......	......	......	......	......	......	$1391^{.7}$ s
			1328^{1} n	......	1271^{4} s	......	......	......	$1286{\cdot}5^{3}$ s	......	1284^{8} n	$1400^{.7}$ s
	N $1383^{.5}$	......	......	......		......	......	......	......	......	......	$1413^{.5}$ s
	N $1394^{.7}$	......	......	......	1307^{1} s	1301^{2} s	......	......	......	......	......	$1419^{.7}$ s
				$1335^{.7}$ s	......	$1305^{2.5}$ s	$1329^{1.5}$ n	......	......	......	......	$1421{\cdot}5^{.7}$ s
						1311^{3} s	......	......	......	......	......	$1434^{.5}$ s
						1324^{3} s	......	......	......	......	......	$1438^{.5}$ s
					$1351^{.5}$ s	......	......	......	......	......	......	$1445^{.7}$ s
						1341^{3} s	......	......	......	......	......	$1446^{.7}$ s
						$1349^{.7}$ h	......	......	......	......	......	$1456^{.7}$ s
						1359^{3} s	......	1356^{1} s	......	1357^{4} s	......	$1459{\cdot}5^{.2}$ s
						1365^{4} s	1376^{1} s	......	1372^{2} s	1366^{4} s	......	$1467^{.7}$ s
						$1397^{2.5}$ s	$1413^{.7}$ s	......	1380^{7} s	1396^{4} s	......	1481^{1} s, d
							1428^{1} s	......	$1421^{.3}$ s	......	......	$1485{\cdot}3^{.5}$ s
						$1425^{.2}$ s	$1438^{.7}$ s	......	$1435^{.3}$ s	$1438{\cdot}3^{4}$ s	......	$1486^{.2}$ s
						$1467^{1.5}$ h	$1443^{.7}$ s	......	1446 h	......	1484^{1} s	$1486{\cdot}5^{.2}$ s
	N $1502^{.2}$	......	......	1506^{1} s	......	......	1452^{2} s	......	......	......	......	$1488^{.2}$ s
	N $1516^{.2}$	......	......	......	......	......	$1456^{.2}$ s	......	......	......	......	1532^{2} s
							$1473{\cdot}5^{3}$ s	......	......	1485^{4} s	......	$1537^{.7}$ s
	N $1537^{.2}$	......	......	......	......	......	$1505{\cdot}5^{.5}$ s	1505^{9} s	......	......	1506^{2} n	$1541^{.5}$ s
							1515^{4} s	......	......	$1548{\cdot}2^{3}$ s	1520^{1} h	$1545^{.5}$ s
											1524^{4} n	$1560^{.2}$ s
							1559 } h	......	......	......	1576^{1} n	$1574^{.2}$ s
							1571 }	......	......	1562^{2} s	......	$1582^{.7}$ s,d
E { 1599	......	......	......	$1599{\cdot}5^{4}$ s	......	......	......	......	......	......	......	$1593^{.5}$ s
1600	......	......	......	......	......	......	......	......	......	......	......	$1599^{.7}$ s
												$1600^{.7}$ s
Solar.	Air.	Na.	K.	Ca.	Ba.	Sr.	Mn.	Tl.	Ag.	Te.	Sn.	Fe.

From D to E.

Cd.	Sb.	Au.	Bi.	Hg.	Co.	As.	Pb.	Zn.	Cr.	Os.	Pd.	Pt.
......	......	1011^{1} n	......	$1008^{1.5}$ n	......	......	1015^{3} n					
......	......	1025^{2} s	1026^{2} n	$1019^{\cdot5}$ n	......	......	......	......	......	1029^{1} s	$1023^{\cdot3}$ s	
......	......	......	......	......	......	......	$1031{\cdot}1^{4}$ s	......	......	......	$1031{\cdot}5$ h	
......	$1041^{\cdot5}$ s	1045^{4} s	1059^{1} n	......	......	1042^{1} n	......	......	......	......	......	$1041^{\cdot5}$ s
......	$1057^{\cdot5}$ s	......	......	$1060^{\cdot3}$ n	......	......	......	......	......	......	......	$1045^{\cdot5}$ s
......	......	......	......	......	......	......	......	......	......	......	$1056^{\cdot7}$ s	
......	1081^{1} n	$1081{\cdot}5^{\cdot5}$ s	......	1074 h	......	......	$1055^{\cdot5}$ n					
......	......	......	......	......	......	......	......	$1062^{\cdot5}$ s	1081^{1} h	......	1068 h	
......	$1145^{\cdot5}$ n	1109^{1} s	......	$1083{\cdot}5^{8}$ n	......	$1090^{\cdot5}$ n	1094^{1} n	......	1087^{1} h	......	......	$1073^{\cdot7}$ d
......	......	......	......	$1100{\cdot}5^{8}$ n	......	......	......	$1110^{\cdot5}$ s	1090^{1} h	$1093^{\cdot5}$ s	1084 h	
......	......	......	1143^{6} n									
......	1158^{1} n	......	......	1177^{2} n	......	......	......	$1122^{\cdot5}$ n				
......	$1189^{\cdot5}$ n	......	1197^{3} n	......	......	......	......	......	......	1141^{1} s	$1127^{\cdot3}$ s	
......	......	$1199^{\cdot5}$ s	......	......	......	......	......	......	......	......	1129^{1} s	
......	......	......	......	......	......	1203^{7} n	......	......	1212^{1} s	......	$1185^{\cdot5}$ s	
......	1207^{1} h											
......	1214^{4} n	......	......	......	......	......	......	......	$1242^{1.5}$ s	......	$1199^{\cdot5}$ s	
......	1220^{1} n	......	......	1252^{1} n								
......	......	$1266^{\cdot5}$ n										
......	1279^{4} n											
......	......	......	1293^{1} s	......	$1039^{\cdot2}$ s							
......	1383^{3} n	......	......	......	$1043^{\cdot2}$ s	......	......	......	......	......	$1212^{\cdot5}$ s	
......	......	......	$1305^{\cdot5}$ s	......	$1207^{\cdot5}$ s	$1231^{\cdot5}$ n	1240^{9}					
......	......	......	......	......	$1217^{\cdot5}$ s	$1257^{\cdot5}$ n	......	......	......	1264^{1} s	1219 } h	
......	......	......	......	......	$1257^{\cdot7}$ s	......	1279^{5} n	$1269^{\cdot5}$ n	......	......	1233 }	
......	......	......	......	......	......	......	......	......	......	......	$1240{\cdot}5^{\cdot5}$ s	
......	......	......	......	......	......	......	......	1283^{1} n	......	......	$1248^{\cdot5}$ s	
......	......	......	......	......	1361^{1} s	1291^{6} n	......	......	......	......	$1259{\cdot}5^{\cdot7}$ s, d	
......	......	......	......	......	$1401^{1.5}$ s							
......	......	......	......	......	$1470^{\cdot5}$ s	......	......	......	......	1322^{2} s	$1281^{1.5}$ s	
......	......	......	......	......	1483^{1} s	......	......	......	......	......	1299^{1} s	
......	......	......	......	1385^{10} n	1491^{1} s	1348^{6} n	......	......	......	......	$1303^{1.5}$ n	
......	......	......	......	......	$1496^{\cdot2}$ s	......	......	......	......	......	$1331^{1.5}$ n	$1367^{\cdot7}$ s
......	......	......	1395^{1} h	......	......	......	......	......	......	$1405^{\cdot5}$ s	$1380^{1.5}$ s	
......	1457 h	......	......	......	$1500{\cdot}5^{2}$ s							
......	......	......	......	$1421^{1.5}$ n	$1501{\cdot}5^{2}$ s	......	......	......	$1439^{1.5}$ s	$1432^{1.5}$ s	$1412^{\cdot5}$ s	
1473^{10} n	1471^{3} n	......	1453^{1} h	......	$1508^{\cdot2}$ s	1443^{1} n	......	......	......	......	1456^{2} s	$1459^{\cdot5}$ s
......	......	......	......	$1487^{\cdot5}$ n	1514^{4} s	......	......	......	$1507{\cdot}5^{\cdot7}$ s	......	$1492^{\cdot5}$ s	$1484^{\cdot5}$ s
......	......	......	......	......	$1525^{\cdot5}$ n,d	1465^{1} n	......	......	1510^{1} s			
......	......	......	1495^{1} h	......	$1534^{\cdot5}$ s	......	1479^{7} n	......	......	......	$1511^{\cdot5}$ s	
......	1501	......	......	......	$1539^{\cdot3}$ s	......	......	......	......	......	$1548^{\cdot5}$ s	
1517^{10} n	......	......	......	......	$1543^{\cdot2}$ s	......	......	......	1532^{1} s	......	......	1561^{2} s
......	......	......	......	......	$1549^{\cdot5}$ s	......	......	$1519^{\cdot5}$ n	......	......	1569^{3} s	
1556^{1} n	......	......	......	......	$1573^{\cdot2}$ s	1529^{6} n	......	......	1567^{1} s, d			
......	......	......	......	......	$1579^{\cdot2}$ s							
......	......	......	......	$1583^{\cdot5}$ n	$1584^{\cdot2}$ s	1577^{1} n	......	......	$1594^{\cdot7}$ s			
......	......	......	1598^{7} n	......	$1586^{1.5}$ s							
......	......	......	......	......	$1591^{\cdot5}$ s	......	$1593{\cdot}3^{\cdot5}$ n					
Cd.	Sb.	Au.	Bi.	Hg.	Co.	As.	Pb.	Zn.	Cr.	Os.	Pd.	Pt.

N.B. In the column Ba the line 1271^{4} should be 1308^{4} and the line 1307^{1}, 1327^{1}.

TABLE III.

Solar.	Air.	Na.	K.	Ca.	Ba.	Sr.	Mn.	Tl.	Ag.	Te.	Sn.	Fe.
E { 1599												
1600												
				1605^{3} s	......	......	......	......	......	......	......	1603·5 s
				1609·5 s	......	1617^{3} s	1617·5 s	......	......	......	......	1608·5 s
				$1612^{1\cdot5}$ s	......	1638^{2} s	......	......	......	1658·5 n	......	1613·3 s
	O 1678·5	......	......	......	......	$1651^{1\cdot5}$ s	......	......	......	......	1657^{2} n	1621·3 s
						$1656^{1\cdot5}$ s	......	......	1675^{5} n	......	......	1632·3 s
	O 1699·5	......	......	......	......	$1659^{1\cdot5}$ s	......	......	......	......	......	1645^{1} s
	N 1713 h	......	......	1702^{1} s	......	1665^{1} s	......	......	......	......	......	1653^{1} s
b { 1708	N 1718 h *	......	......	......	......	1745^{1} s	......	......	......	......	......	1662·5 s, d
1723	N 1721 h	......	......	......	......	......	......	1747^{4} n	......	......	......	1691·3 s
1731·5	... ..	......	......	......	......	......	......	......	......	......	......	1696·3 s
	O 1737·3	......	......	......	......	......	......	......	......	1773^{1} n	......	1698·5 s
		1746^{1} n	......	......	......	......	......	......	......	......	......	1713·7 s
		1753·5 n	......	......	......	......	......	......	......	......	......	1728^{1} s
												1731·5 s
												1753·3 s
						1817·5	......	1851^{4} n	......	......	......	1767·7 s
	N 1860·5	......	......	......	......	......	......	......	......	......	1821^{3} n	1775·5 s
												1821 h
	N 1900^{3}	......	......	1907·7 s	......	......	......	1885^{1} s	......	1909·5 n	......	......
	N 1929·7	......	......	......	......	......	......	......	......	......	......	......
	N 1941·5	......	......	1935·3 s	......	......	......	......	......	......	......	......
	N 1951·5	......	......	......	......	......	......	......	......	......	......	......
	N 1956·5	......	......	......	......	......	......	......	......	......	......	1940^{1}·5 s
	N 1960·5^{10}											
	N 1967^{10}											
	N 1978·5											
	N 1990·3	......	......	......	......	......	......	......	......	......	......	......
		1991 h										
								1999^{2} h	......	......	......	......
	O 2043·5	......	......	......	......	2021^{1} s	......	......	......	......	......	$2036^{1\cdot5}$ s
	O 2060·7	......	......	......	......	2029^{2} s						
	N 2079·5	......	......	......	......	2060 h	......	2146^{2} s				
	O 2089·5	......	......	......	2075^{9} n	2145^{1} s	......	......	......	......	......	......
	O 2119·5											
	N 2140·5	......	......	......	......	$2176^{1\cdot5}$ s	......	......	......	......	......	2092^{1} s
	O 2145·5	......	......	......	2133^{4} n	......	......	......	......	......	......	2098·7 s, d
	N 2168·5	......	......	......	......	......	......	......	......	......	......	......
												2147^{1} s
				2172·7 s								
	O 2181·5	......	......	......	......	$2180^{1\cdot5}$ s						
						2185^{1} s	......	......	......	......	......	......
	N 2192·3	......	......	......	......	......	......	......	......	......	......	......
										2191^{1} h	......	......
F 2200												
Solar.	Air.	Na.	K.	Ca.	Ba.	Sr.	Mn.	Tl.	Ag.	Te.	Sn.	Fe.

* When the induction spark is taken in oxygen, a faint line is seen nearly in the position of the nitrogen line 1718. Since the lines of oxygen have a diminished intensity when the spark passes in air, this line would be too faint to be distinctly observed in the air-spectrum, in which it occurs in a position of close proximity to brighter lines of nitrogen.

From E to F.

Cd.	Sb.	Au.	Bi.	Hg.	Co.	As.	Pb.	Zn.	Cr.	Os.	Pd.	Pt.
......	......	......	......	......	$1602^{\cdot 3}$ s	......	......	......	$1605{\cdot}5^{1}$ s			
......	......	......	......	......	1604^{3} s	......	......	......	1607^{1} s	......	$1617^{\cdot 5}$ s	
......	1636^{3} h	......	......	......	$1617^{\cdot 5}$ s	1648^{4} n	......	......	$1619^{\cdot 5}$ s	......	$1622^{\cdot 5}$ s	
......	......	1647^{5} s	......	......	$1619^{\cdot 3}$ s	......	......	1626^{1} n	$1626^{\cdot 5}$ s	......	$1642^{1\cdot 5}$ s	1653^{1} s
......	1661^{1} s	......	......	$1662^{\cdot 3}$ h	$1622^{\cdot 5}$ s	......	......	......	$1640^{\cdot 5}$ s	......	$1674^{\cdot 7}$ s	
......	......	......	1675^{10} n	......	$1626^{\cdot 3}$ s	......	......	$1645^{\cdot 5}$ n	......	$1683^{\cdot 5}$ s		
......	......	......	1685^{1} n	......	$1642^{\cdot 5}$ s	......	1685^{1} s	......	$1657^{\cdot 7}$ s			
......	1715^{3} h	......	......	......	$1650^{\cdot 5}$ s	......	......	......	1677^{4} s			
1747^{1} s	......	......	1759^{7} n	......	$1670^{1\cdot 5}$ s	1737^{1} n	1698^{1} n	......	1680^{3} s	......	......	$1689^{\cdot 3}$ s
......	1765^{3} h	......	......	$1777^{\cdot 5}$ h	$1685^{\cdot 5}$ s	......	......	......	$1681{\cdot}5^{3}$ s			
......	......	......	1787^{6} n	......	$1699^{\cdot 5}$ s	......	......	$1743^{\cdot 5}$ n	......	......	1735^{2} s	
......	......	......	......	......	$1707^{\cdot 5}$ s	......	$1735^{\cdot 5}$ n	......	1749^{2} n			
......	1803^{3} h	......	......	......	$1743^{\cdot 5}$ s	......	......	$1790^{\cdot 5}$ n				
......	......	......	1834^{1} n	......	$1756^{\cdot 5}$ s	......	......	$1797^{\cdot 5}$ n	......	......	$1798^{1\cdot 3}$ s	
1843^{10} s	......	......	......	......	1781 n							
......	1849^{1} s	......	$1851{\cdot}3^{5}$ n	......	1813 h	1814^{5} n	......	......	$1815^{\cdot 7}$ n	......	1807^{1} s	
......	......	$1869^{\cdot 5}$ s	......	......	......	......	......	$1845^{\cdot 5}$ n				
......	......	......	......	......	$1857^{\cdot 5}$ h	......	......	1859^{1} n	......	$1859^{\cdot 5}$ s		
......	1900^{2} h	......	......	......	$1876^{\cdot 3}$ s	......	$1900{\cdot}3^{2}$ n	$1893^{\cdot 5}$ n	......	......	$1873^{\cdot 5}$ s	1879^{1} s
......	......	......	......	......	$1887^{\cdot 3}$ s							
......	1919^{2} h											
......	......	......	......	......	$1925^{\cdot 5}$ s							
......	......	......	1979^{1} h									
......	......	......	......	......	......	1993^{2} n						
			2015^{1} h	......	$2021^{\cdot 5}$ s							
......	......	......	......	2033^{1} h	......	......	......	$2016^{\cdot 5}$ n				
......	2051^{3} n	......	......	......	......	......	......	2091^{3} n	2097^{1} s			
......	......	......	......	$2101^{\cdot 5}$ h	......	......	......	2110^{8} n				
......	......	......	$2105^{\cdot 5}$ n									
......	......	......	2119^{1} n									
......	......	......	......	......	......	2153^{1} n	......	......	2156^{1} s	......	$2175^{1\cdot 5}$ s	
......	2171^{3} n	......	......	......	......	......	......	......	$2175^{\cdot 7}$ s			
......	......	......	......	......	2186^{3} s	......	......	......	$2181^{\cdot 3}$ s			
......	......	......	......	......	......	......	......	$2191^{\cdot 5}$ n	$2198^{\cdot 5}$ s			
Cd.	Sb.	Au.	Bi.	Hg.	Co.	As.	Pb.	Zn.	Cr.	Os.	Pd.	Pt.

TABLE IV.

Solar.	Air.	Na.	K.	Ca.	Ba.	Sr.	Mn.	Tl.	Ag.	Te.	Sn.	Fe.
F 2200	N 2205$^{\cdot5}$	......	......	......	......	2213^{1} s						
	O 2213$^{\cdot3}$											
	N 2221$^{\cdot3}$											
	N 2305^{2}	......	......	......	......	2254$^{1.5}$ s	2267^{6} s	......	......	2245^{1} h	2205^{3} n	......
	N 2336^{1}	......	......	......	......	2291$^{1.7}$ s	2343^{5} s	......	......	2341$^{\cdot5}$ h	......	......
	N 2350$^{\cdot7}$	......	2260^{2} n	......	......	2343$^{1.5}$ s	2379^{6} s	......	......	2497 h	......	......
	O 2502$^{\cdot7}$ n	......	......	......	......	2410$^{\cdot5}$ s	2385^{5} s	2379^{2} n	......	......	......	......
	O 2512$^{\cdot7}$ n	......	......	......	......	2427^{1} s	2401^{5} s	......	......	2595^{1} n	......	......
	O 2563$^{\cdot5}$ n	......	......	......	2459$^{\cdot5}$ s	2469^{1} s	2433^{1} s	2437^{4} n	......	2613^{1} n	......	......
	O 2597$^{\cdot5}$ n	......	......	......	......	2726^{5} n	2456^{1} s	......	......	......	......	......
	O 2626^{2}	......	......	......	......	......	2492 h	......	......	......	2777^{2} n	2781$^{\cdot5}$ s
	N, O 2642^{2} d	......	......	......	2535$^{\cdot5}$ s	......	......	......	......	2730^{1} n	......	......
	N 2669^{3}	......	......	......	......	......	......	......	......	2739^{1} n	......	......
	N 2689^{1}	......	......	......	......	......	......	......	......	......	......	......
	N 2707^{1}											
	N 2722$^{1.5}$											
	N 2738$^{1.5}$	......	......	......	......	......	......	......	......	......	......	......
	O 2748^{1}	......	......	2777$^{\cdot5}$ s	......	......	......	......	......	......	......	......
	O 2766^{1}	......	......	2784$^{\cdot3}$ n	......	......	......	......	......	......	......	......
	N 2856 h	......	......	2792$^{\cdot2}$ s	2856^{9} s	......	......	......	......	......	......	......
	N 2904 } h	......	......	......	......	......	......	......	......	2875 h	......	......
	N 2978 }	......	......	......	......	......	2987$^{\cdot7}$ s	......	......	......	......	......
	N 3009^{1}	......	......	......	2931^{3} n	......	2999$^{\cdot7}$ s	......	......	......	......	......
	N 3011^{1}	......	......	......	......	......	3021 ^{1} s	......	......	......	......	3272$^{1.5}$ s
	N 3056 h											
	O 3086 h	......	......	......	......	......	3054^{1} s	......	......	......	2931^{4} n	......
	N 3144 d	......	......	3124^{3} s	......	......	3097^{1} s	......	......	3051^{1} h	......	3341^{2} s
	N 3174 } h	......	......	3181^{3} s	......	3169^{1} s	3102^{2} s	......	......	......	......	3532$^{1.5}$ s
	N 3219 } h	......	......	......	......	......	3114^{1} s	......	......	3435$^{\cdot5}$ n	......	......
	O 3238^{1} n	......	......	3212^{2} s	......	......	3120^{1} s	......	......	......	......	......
	O 3241^{1} n	......	......	......	......	3389$^{\cdot5}$ n	3131$\cdot$5$^{\cdot3}$ s	......	......	......	......	......
	N 3292 h	......	3328^{2} n	3561^{3} s	......	3409$^{\cdot5}$ n	3133^{2} s	......	......	......	......	......
	O 3395^{1} n	......	......	3602$\cdot$5$^{2.5}$ s	......	......	3141^{1} s	......	......	......	......	......
	O, N 3456^{2} n	......	......	3617^{4} s	......	3489^{1} n	3180^{1} s	......	......	......	......	......
G 3597	O 3560^{1} n,d	......	3591$^{1.5}$ n	3628$^{2.5}$ s	......	3553^{1} h	3242^{1} s	......	......	......	......	3597$^{1.5}$ s
	O 3710 h	......	......	3665^{3} s	......	3604^{5} n	3691^{1} s	......	......	......	......	3610$^{1.5}$ s
	N 3863 h	......	3762^{2} n	3692$^{2.5}$ s	......	......	3749^{1} s	......	......	3619^{2} n	......	3623$^{\cdot5}$ s
	N 3991 h	......	......	......	......	3952^{5} n	3782^{1} s	......	......	......	......	3645$^{\cdot5}$ s
	O 4059^{1}	......	......	3909^{6} s	......	......	......	......	......	......	......	3728^{2} s
	O 4087^{1}	......	4082^{3} n	......	......	4181^{3} n	3870^{3} s	......	......	......	......	3773$^{1.5}$ s
	N 4145 h	......	......	......	4167^{2} n	......	......	......	......	3779 h	......	3812$^{1.5}$ s
	O 4232	......	......	......	......	......	......	......	......	......	......	......
	N 4263^{1} n	......	......	......	......	......	......	......	......	......	......	4009^{1} s
	N 4330 h	......	......	......	4332^{5} n	......	......	......	......	......	......	4019^{1} s
	O 4395^{2}	......	......	......	......	......	......	......	......	......	......	4221^{1} s
	N 4473^{1} n	......	......	......	......	......	......	4443^{3} n	......	......	......	4267^{1} s
	N 4505^{1} n	......	......	......	......	......	......	......	......	4703^{3} h	......	4323^{1} s
	O 4615^{1} n	......	......	......	......	4599^{3} n	......	......	......	......	......	4633^{1} s
	O 4639^{1} n	......	4791^{3} n	......	......	......	......	......	......	......	......	4671^{1} s
	N 4821 h	......	......	......	......	......	......	......	......	......	......	4781^{1} s
	N 5077$^{\cdot7}$	......	......	......	......	......	......	......	......	......	......	......
H 5277	....	......	......	5277^{6} n								
Solar.	Air.	Na.	K.	Ca.	Ba.	Sr.	Mn.	Tl.	Ag.	Te.	Sn.	Fe.

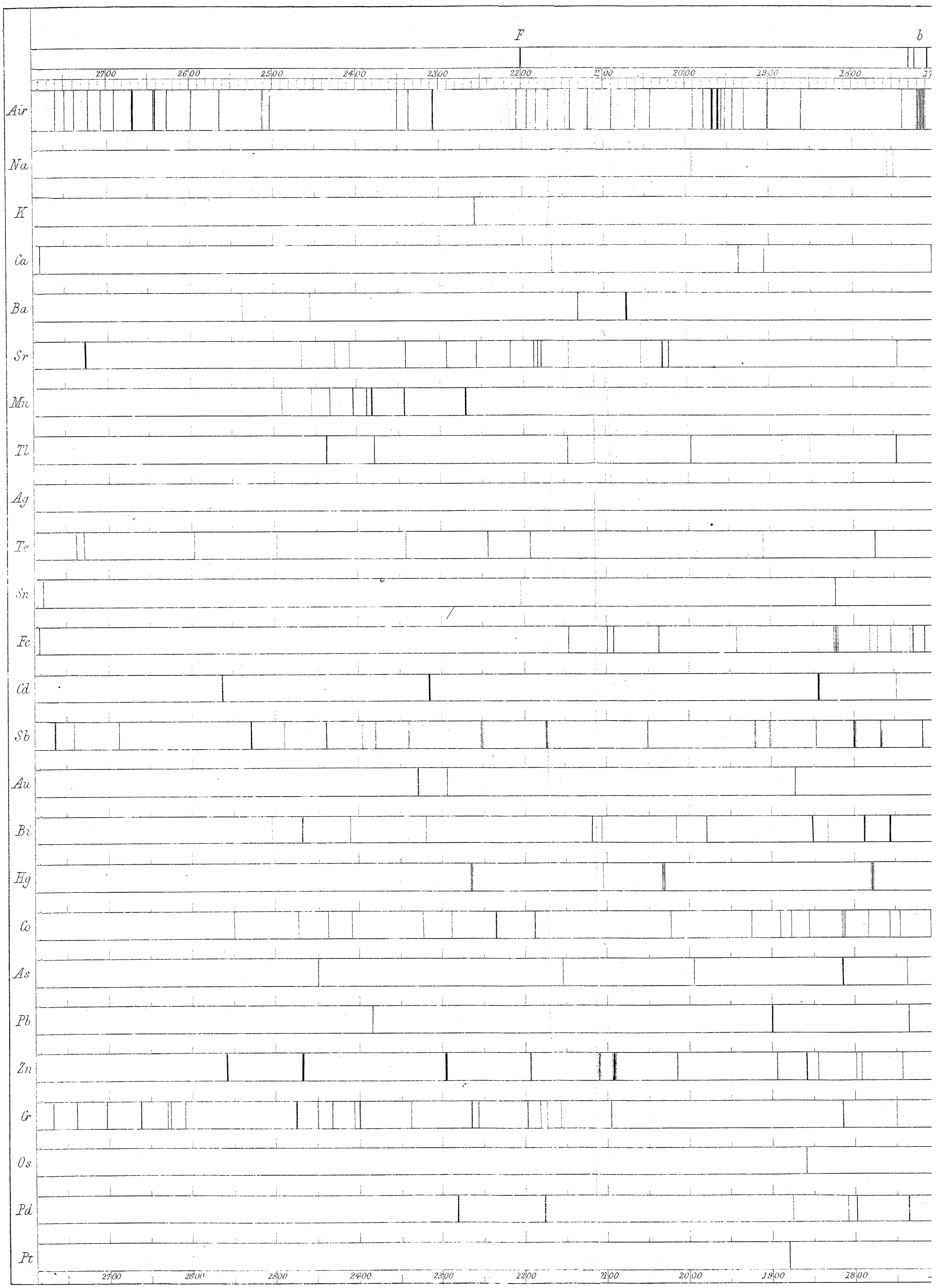
From F. to H.

Cd.	Sb.	Au.	Bi.	Hg.	Co.	As.	Pb.	Zn.	Cr.	Os.	Pd.	Pt.
......	2251^{2} n	......	......	......	......	......	......	......	$2257^{\cdot 5}$ s			
2315^{8} s	2339^{2} h	......	......	......	......	......	......	......	$2266^{1\cdot 5}$ s			
......	2377^{2} h	$2291^{\cdot 5}$ s	......	......	2236^{3} s	......	......	......	......	......	$2279{\cdot}5^{2}$ s	
......	2397^{2} n	......	......	$2263^{\cdot 5}$ n	......	......	......	2294^{7} s	$2336^{\cdot 7}$ s			
2562^{6} s	2440^{2} n	2326^{4} s	2317^{1} n	......	2286^{2} s							
......	2488^{3} n	......	......	......	2325^{1} s	......	2384^{3} n					
......	......	......	2408^{1} n	......	$2409^{\cdot 5}$ s	......	......	......	2400^{1} s			
......	2529^{3} n	......	2467^{5} n	......	$2438^{\cdot 5}$ s	2450^{1} n	......	......	$2406^{\cdot 5}$ s			
......	2687^{1} h	......	2453^{1} n	......	$2471^{\cdot 5}$ s	......	......	2469^{6} s	$2435^{\cdot 7}$ s			
......	2740^{1} h	......	2502^{1} n	......	$2550^{\cdot 5}$ s	......	......	......	$2452^{\cdot 7}$ s			
......	2763^{2} n	......	......	......	......	......	......	......	2474^{1} s			
......	......	......	......	......	......	......	......	2559^{4} s				
......	......	......	......	......	2785^{2} n							
......	......	......	......	......	......	......	......	......	2619^{1} s			
......	......	......	2837^{5} n	......	......	......	......	......	$2627^{\cdot 7}$ s			
......	2977^{2} n	......	......	......	2823^{1} n	2859^{1} h	......	......	$2632^{1\cdot 5}$ s, d	......	......	2857^{1} s
......	......	......	3060^{1} n	......	......	2897^{1} h	......	......	$2663^{\cdot 5}$ s			
......	......	......	......	......	2862^{1} s	......	......	......	$2701^{\cdot 7}$ s			
......	......	......	......	......	......	......	......	......	......	......	......	$2936^{\cdot 5}$ s
......	......	$3026^{2\cdot 5}$ s	......	......	2910^{3} s	......	......	......	$2740^{\cdot 7}$ s			
......	3115^{1} n	......	......	......	......	......	......	......	$2768^{\cdot 7}$ s	......	......	$2999^{\cdot 7}$ s
......	......	......	......	......	......	......	......	......	......	......	$3065^{\cdot 7}$ s	
3239^{4} s	......	......	......	......	......	$3006^{1\cdot 5}$ h	......	......	$2840^{\cdot 7}$ s	$2861^{\cdot 7}$ s		
......	3359^{1} h	......	......	......	......	......	......	......	$2871^{\cdot 7}$ s			
......	......	......	......	......	......	......	......	......	$2887^{\cdot 7}$ s	3225^{2} s	......	3156^{1} s
......	......	......	3315^{2} n	......	......	$3097^{2,5}$ h	......	......	$2899^{\cdot 7}$ s	3421^{1} s		
......	......	......	......	......	......	......	......	......	2914^{1} s			
......	3446^{4} n	......	3481^{3} n	3421^{8} n	......	......	......	......	2927^{1} s	3583^{1} s		
......	......	......	......	......	......	......	3329^{7} n	......	3007^{1} s			
......	......	......	3519^{2} n	......	......	......	......	......	3444^{2} s	3645^{1} s	......	3525^{1} s
......	3756^{3} n	......	......	......	......	3381^{1} n	......	......	3465^{1} s			
......	3819^{1} n	......	3619^{5} n	......	......	......	......	......	3473^{1} s			
......	$4043^{1\cdot 5}$ n	......	......	......	......	3497^{1} n	......	......	3489^{1} s			
......	......	......	3778^{5} n	......	......	......	3730^{2} n	......	3663^{3} s	3773^{3} s		
......	......	......	......	......	......	......	......	......	3719^{3} s			
......	......	......	......	......	......	......	......	......	3797^{3} s	......	3963^{4} s	
......	......	......	......	......	......	......	3831^{6} n	......	3905^{1} s			
......	......	......	......	......	......	......	......	......	3951^{1} n			
......	......	......	......	......	4388^{3} n							
......	......	......	4378^{4} n	4775^{4} n	4394^{3} n							
......	......	......	......	......	4437^{1} n							
......	......	......	4603^{3} n									
......	......	......	......	......	4523^{1} n	......	4713^{7} n					
......	......	......	......	5158^{3} n								
Cd.	Sb.	Au.	Bi.	Hg.	Co.	As.	Pb.	Zn.	Cr.	Os.	Pd.	Pt.

Note to Plates I. and II.

The scale upon which the spectra have been laid down limits the intensity that can be given, in the engraving, to the stronger lines. From this cause the spectra, as engraved, appear too faint. If greater force had been given to the lines, by making them broader, they would, in several spectra, have occupied singly the space in which two or more lines have to be laid down. This deficiency in strength of some of the lines is more appreciated by the eye, in consequence of the shortness of the lines of the spectra, with the exception of those of the air-spectrum. The narrowness of the spectra of the metals is unavoidable, if the great advantage of having all the spectra upon one Plate is retained.

In some of the spectra bands of unresolved light occur; these, in the Plates, are crossed with lines that they may be distinguished from groups of fine lines.



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1900
1800
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K
Ca
Ba
Sr
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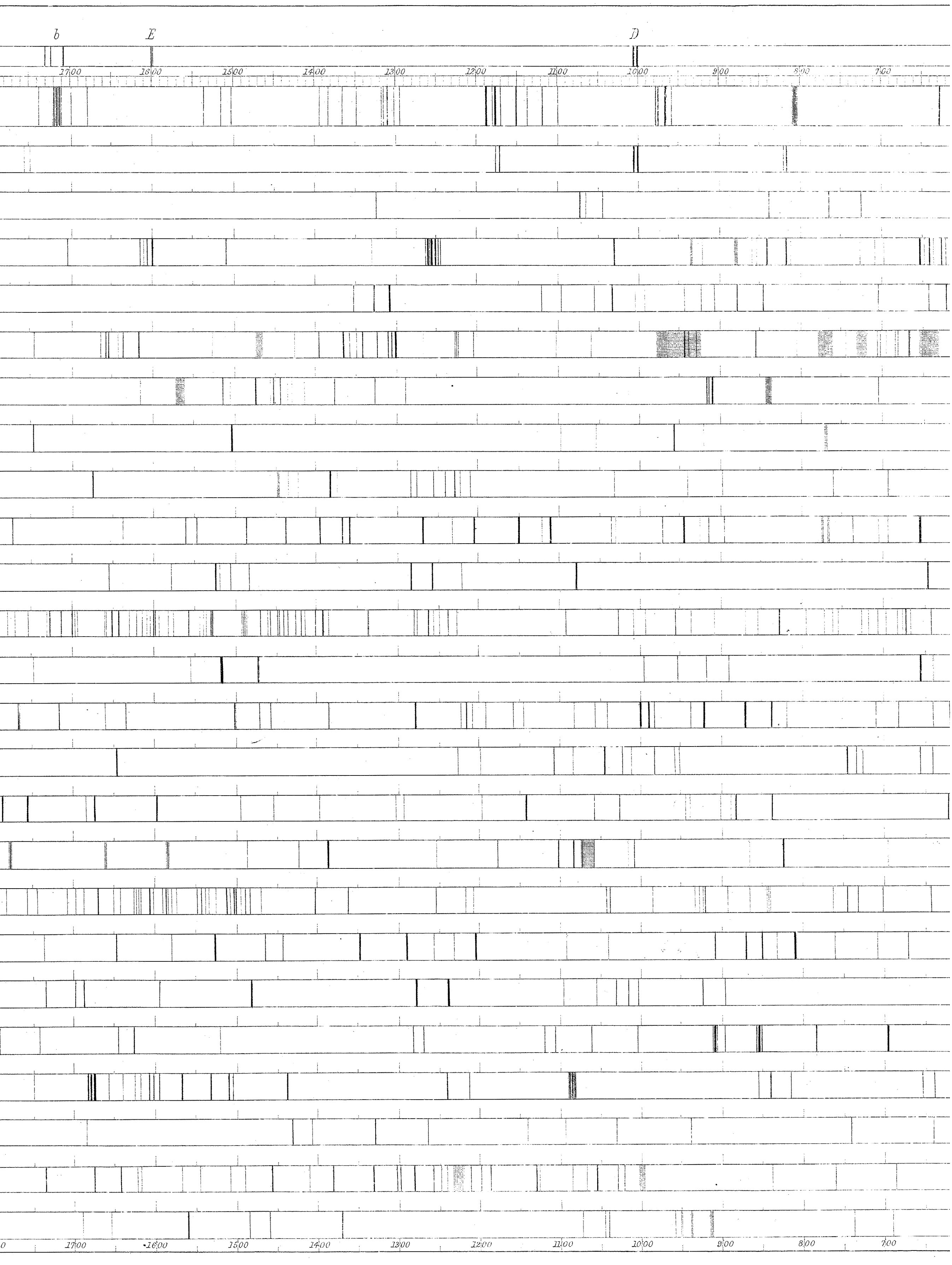
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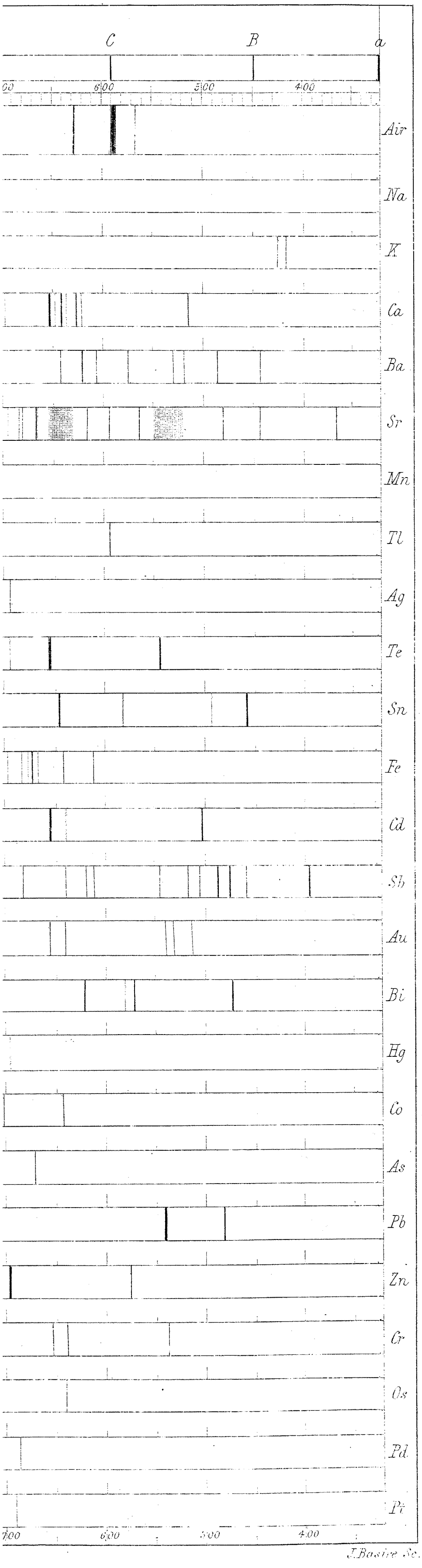
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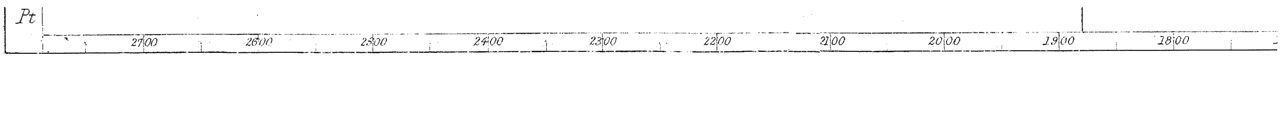
J. Basire Sc.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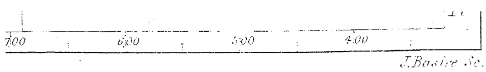

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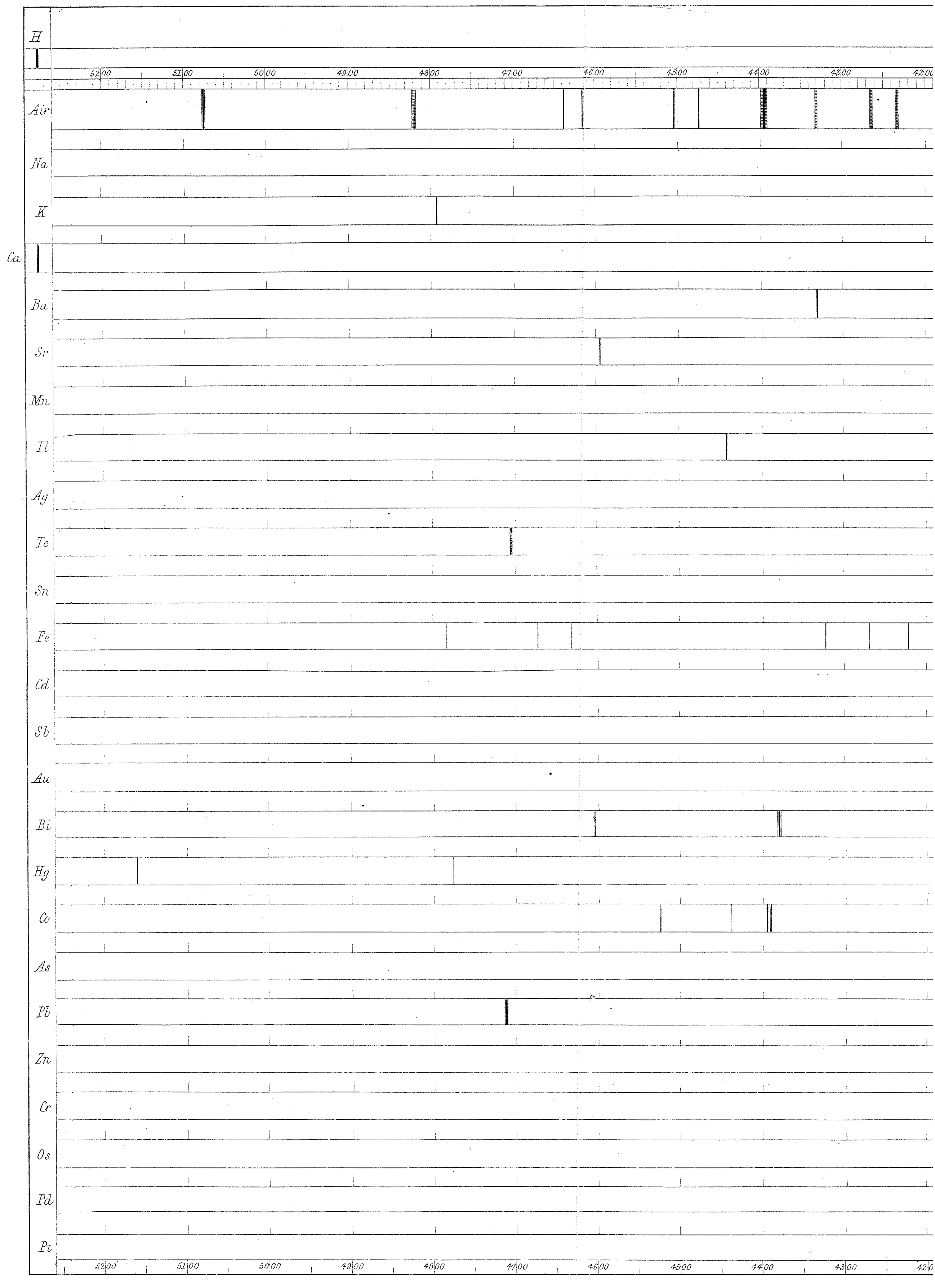
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Fe
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Bi
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Co
As
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Os
Pd
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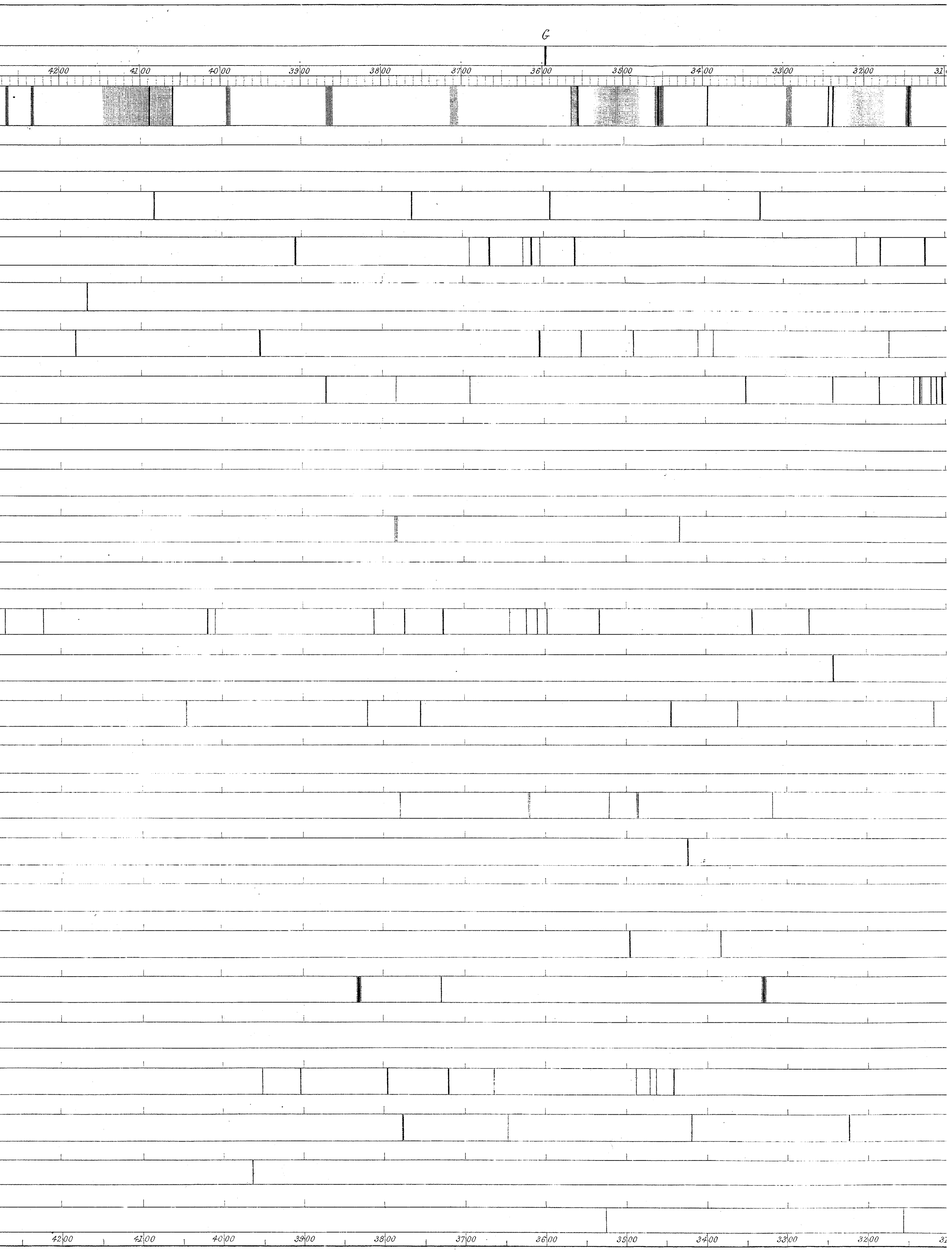
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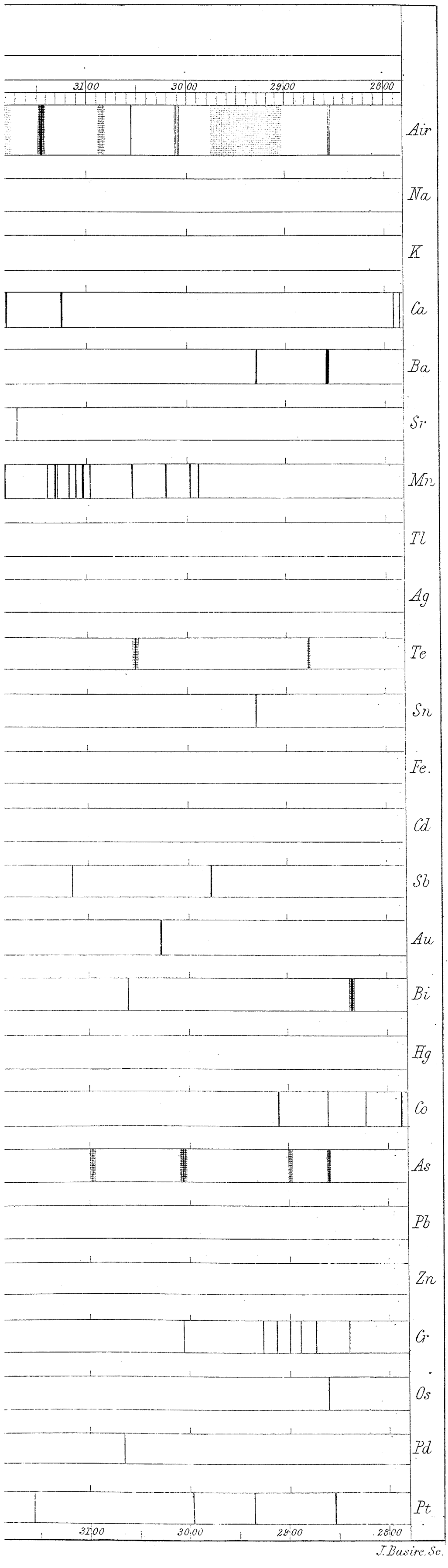
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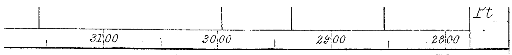

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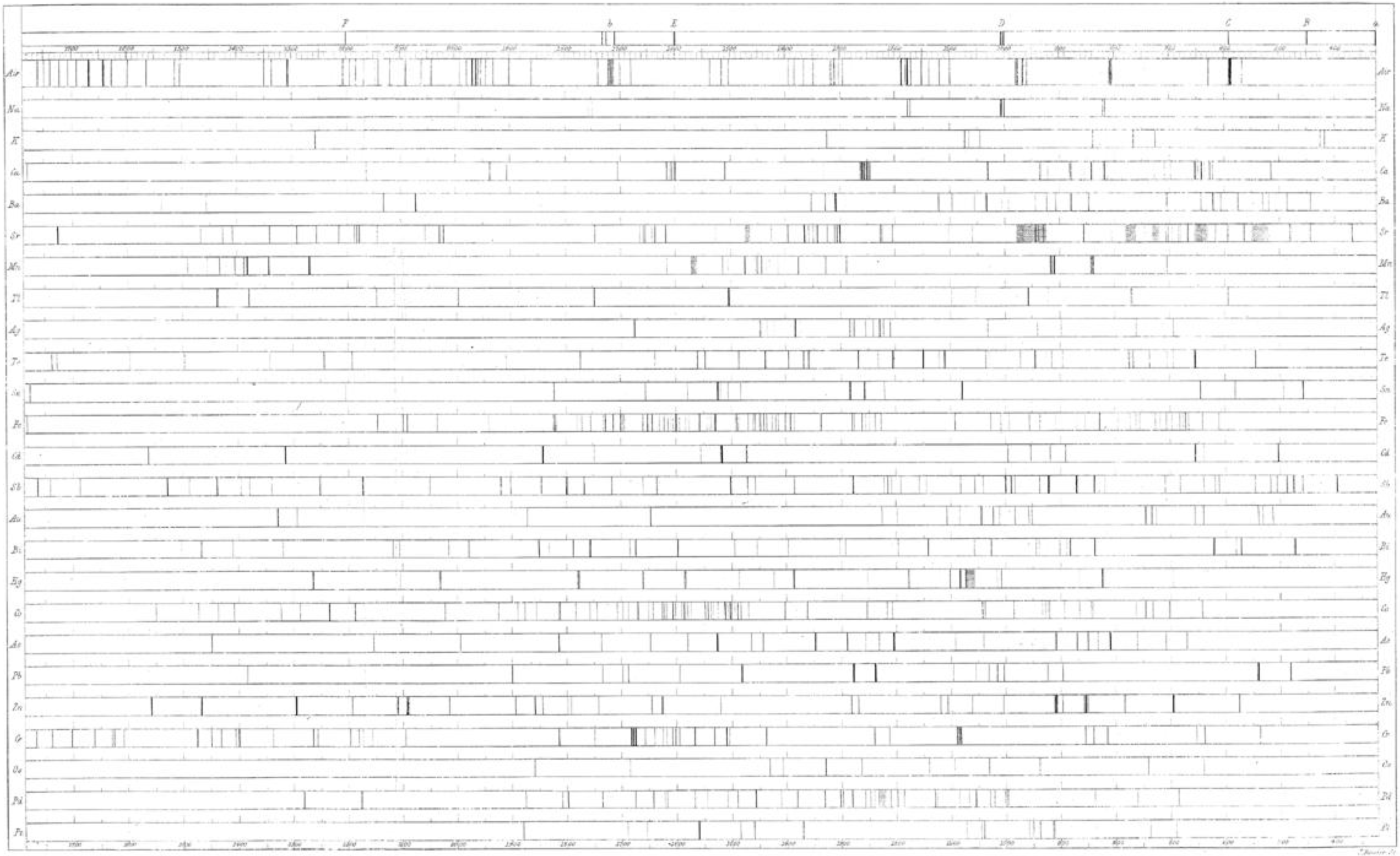
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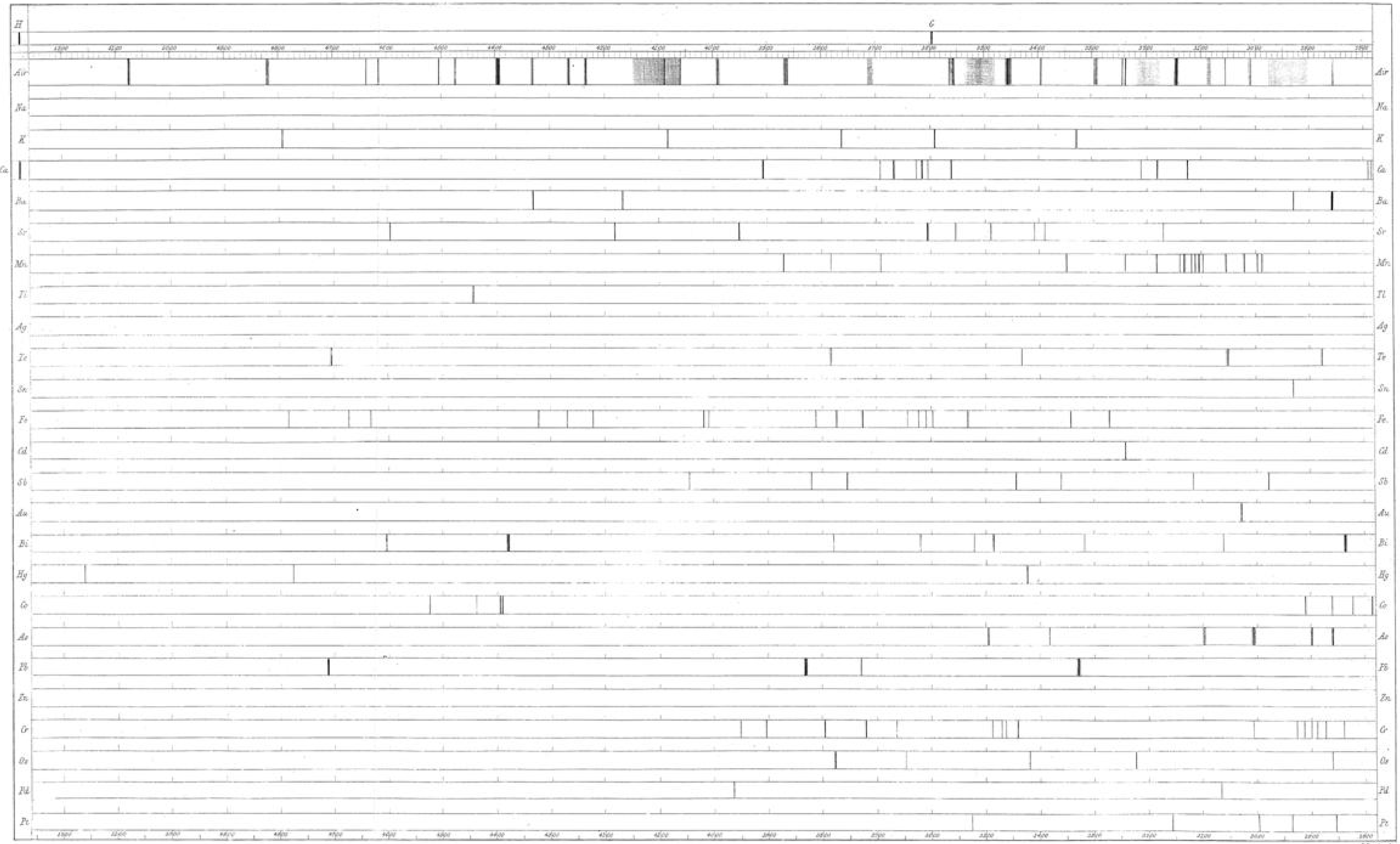
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