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# Flame Spectra at High Temperatures. Part I. Oxy-Hydrogen Blow-Pipe Spectra

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# V. *Flame Spectra at High Temperatures.*—Part I. *Oxy-hydrogen Blow-pipe Spectra.*

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[Plates 6, 7.]

Sir David Brewster, in 1842, appears to have been the first to examine the spectra of salts by means of the oxygen and coal-gas flame, about 180 of which were deflagrated in a platinum spoon (Edinburgh 'Roy. Soc. Proc.,' vol. 6, p. 145).

Professor Norman Lockyer* has given us a map of metallic spectra at the temperature of the oxygen and coal-gas blow-pipe ('Roy. Soc. Proc.,' vol. 23, p. 120). The region observed in the case of twenty-two metals does not extend beyond wave-length 4000 ; and, although we have both arc and spark spectra for the region up to wave-length 1800, we are still unacquainted with the spectra of elements and compounds obtained by means of flames at high temperatures in the ultra-violet region.

## *Methods of Obtaining Spectra with Flames at High Temperatures.*

In studying the spectra of flames there are many points worthy of consideration arising from the structure of the flame, the nature of the combustible, the heat evolved during combustion, and the temperature attained. The temperature of a candle-flame is high enough to give all the spectra capable of being produced by the oxy-hydrogen blow-pipe, for by such simple means we can melt Wollaston's platinum wires and produce the band spectrum of carbon. The reason for such a flame being practically useless for spectroscopic purposes does not arise from the temperature being too low, but from the area of maximum temperature being too small, so that the material to be tested and the support upon which it is held in the flame exercise

* [The following quotation contains a passage which is perhaps the earliest reference to such spectra :—

"The pure earths, when violently heated, as has recently been practised by Lieutenant Drummond, by directing on small spheres of them the flames of several spirit lamps urged by oxygen gas, yield from their surfaces lights of extraordinary splendour, which, when examined by prismatic analysis, are found to possess the peculiar definite rays in excess which characterize the tints of flames coloured by them ; so that there can be no doubt that these tints arise from the molecules of the colouring matter reduced to vapour, and held in a state of violent ignition." 'Light,' Sir. J. F. W. Herschel, London, 1827, also 'Encyclopædia Metropolitana.' p. 438, vol. 4, 1845.—W. N. H., September 29, 1893.]

too great a cooling power. A candle or gas flame owes its shape to the rapid ascension of heated combustible vapour and air, or air and gas mixed, and the maximum temperature is to be found near the tip of the flame. The cross section of the flame near its tip should therefore be sufficiently large to completely envelop the support and substance upon it; hence it will be seen that to have a support as small as possible is a distinct practical advantage. For some time a difficulty presented itself in the study of flame spectra of solid substances at high temperatures owing to the necessity which arises for providing an infusible material suitable as a support for the substance to be tested, capable of withstanding the temperature of the oxy-hydrogen blow-pipe flame, and incapable of chemical action upon metallic oxides. I formerly used strips of iridium for the alkaline earths and their salts, but they are quite unsuitable for use with several substances.

I propose to place on record a most convenient method of observing spectra with the oxy-hydrogen flame, and to describe a considerable number of spectra which were photographed preparatory to undertaking the study of spectroscopic phenomena connected with the Bessemer "blow" and the manufacture of steel generally.

The flame of hydrogen, proceeding from a large lead generator, is burnt with compressed oxygen in a small Bunsen blow-pipe, so fixed that the flame is vertical.

The blow-pipe measures 3 inches in length and $\frac{3}{8}$ths of an inch in external diameter. The substances to be examined are supported in the flame on small plates of kyanite about 2 inches in length, $\frac{1}{20}$th of an inch in thickness, and $\frac{1}{4}$th of an inch in width.

This mineral, which is found in large masses in C°. Donegal, contains 96 per cent. of aluminium silicate, a practically infusible material. It was analyzed in my laboratory some years ago, and owing to the intractable nature of the mineral, the analysis was made with some difficulty.

It is exceedingly difficult to pulverize it, but it readily splits into laminæ.

### *The Instruments and Method of Photography Employed.*

The instrument used for the first series of experiments had but one quartz prism of 60°, composed of right and left handed halves, each of 30°. The photographic plates used were "Ilford rapid" and EDWARDS' Isochromatic Plates.

A number of experiments were made with various sensitizers, such as erythrosine used by WATERHOUSE and by MALLMANN and SKOLICK, and cyanine, employed by V. SCHUMANN. Their use proved advantageous in rendering gelatine emulsion plates sensitive to the yellow and red rays.

It was found that diphenylamine blue, used in a similar manner as, and mixed with, cyanine, rendered gelatine-bromide plates rather more sensitive in the region between E and F of the solar spectrum. SCHUMANN has found that emulsions made with 5 parts of silver iodide, precipitated along with 95 parts of silver bromide, are also sensitive in this part of the spectrum.

A trial was made with various developers in order to ascertain which were the most suitable. The spark spectrum of cadmium was photographed on plates of the same kind, with an exposure of five seconds in each case, and development was carefully timed. Developers containing the following reducing substances were used:—(1) pyrogallol, (2) eikonogen, (3) amidol, (4) rodinol, (5) hydroxylamine hydrochloride, (5) hydroquinol, (6) ferrous oxalate, already prepared from potassium oxalate and ferrous sulphate, (7) ferrous oxalate, prepared just prior to use by mixing ferrous sulphate and potassium oxalate solutions kept separate.

Some years ago a similar trial of the then existing developers was made by me and preference was given to hydroxylamine hydrochloride, as prescribed by Egli and Spiller, because it gave a brown deposit of silver showing under the microscope no structure or granulation. A commercial sample of the salt, recently purchased, which proved to be strongly acid, was recrystallized from hot alcohol and rendered neutral. It gave good results, but the image was slow in appearing.

Freshly prepared ferrous oxalate was excellent, but best of all was hydroquinol, because it not only produced a dense black image with as much freedom from granulation as any other substance, but it also reproduced lines of feeble intensity, and it developed completely in three minutes as against seven minutes for hydroxylamine, and four or five minutes for other substances.

Granulation appears to be caused by a condition of the gelatine now generally used rather than by the nature of the developing solution as was formerly the case. It was decided to use sensitized plates and hydroquinol as a developer.

### *Method of Measuring the Positions and Wave-lengths of Lines.*

The most convenient and simple method of measuring the spectra emitted by flames is to take a photograph of the spark spectra of tin-cadmium and lead-cadmium alloys superposed upon the former. From the lines of these metals and those of air which accompany them we obtain measurements from which, by an interpolation curve, the oscillation-frequencies and their corresponding wave-lengths may be ascertained.*

The measurement of the lines is made in the same manner as the measurement of the bands in absorption spectra, namely, by simply applying to the photograph an ivory scale which is divided into hundredths of an inch, and by means of a lens or low-power microscope with cross wires in the eye-piece, reading by judgment to tenths of each division. To do this with the greatest accuracy it is necessary to have a straight line ruled down the middle of each spectrum, against which the edge of the scale is fixed in position. To rule this line a very slight nick is made in the jaws of the slit of the spectroscope, which admits more light at this than at any other point, and causes a feeble continuous spectrum to be photographed; upon this the

* Several prominent iron lines beyond $\lambda$ 3900 were used in drawing the curve.

lines due to the flame spectra are marked out by the appearance of minute dots Where the insensitive portion of the film occurs, strong lines are easily seen on the continuous linear spectrum in consequence of the slit being slightly widened for a minute portion of its length, so that the effect caused by want of sensitiveness in the silver salts is diminished.

It is a little difficult to read the measurements and describe the spectra at the same time, hence enlargements were made upon which the measurements were recorded as they were read off. Another convenient plan was to adjust the scale to the photograph and take an enlargement therefrom at once, so that prints from the same give approximately their own measurements. Only those measurements are exact which are exactly at the centre of the photographic lens, even when the scale is precisely adjusted to the photograph, so, for instance, that the 20th division was exactly at the sodium line. In cases where the lines were not newly discovered, and it was only necessary to identify them, nothing more was required. New lines and bands were measured by a micrometer screw with a pitch of 100 threads to the inch, and a wheel head divided into 100 parts. The screw carries a nut on which a microscope, magnifying 10 diameters, is fixed, by which arrangement it is easy to measure to $\frac{1}{10,000}$th of an inch, and, where desirable, to $\frac{1}{100,000}$th. This instrument was made by Mr. A. Hilger, of London. Each measurement was recorded at the time by writing on an enlarged print of the same photograph.*

### *The Spectrum seen when supports of Kyanite alone are heated in the Oxy-hydrogen Flame.*

Just as in the ordinary use of the spectroscope we are prepared to see the lines of sodium, and under certain circumstances the bands peculiar to carbon, so in these photographs, the sodium lines and the strongest groups of lines belonging to the emission spectrum of water vapour, are also always present. In addition to these, the kyanite yields the red line of lithium, which is no inconvenience, but a positive advantage, as it serves to indicate where the spectrum commences, and from which point measurements may be made.

### *The Extent and Character of the Spectra observed.*

Although the apparatus is capable of photographing on one plate rays lying between wave-lengths 6708 of lithium in the red and 2194 in the ultra-violet, nevertheless the flame spectra of a large majority of the metals and their compounds terminate somewhere about the ultra-violet emission spectrum of water. The first,

* For several of the enlarged negatives made exactly to the same scale I am indebted to the kindness of my friend, Professor Alec Fraser, who devoted much of his own valuable time to making negatives with as perfect a definition as possible, the prints from which have greatly facilitated my work.

second, and third series of lines measured, Liveing and Dewar, always appear in these spectra; in some cases the fourth and fifth series are well rendered.

Although the number of lines exhibited by some of the metals is large, yet the extent of spectrum is small compared with that yielded by condensed sparks. Typical band spectra are exhibited by sulphur, selenium, and tellurium. The first yields a continuous spectrum, in which a series of beautiful bands is seen, the second a series of fine bands occurring at closer intervals, the third is characterized by bands still closer together, and near the more refrangible termination of which four lines occurring in the spark spectrum of tellurium are visible.

Thus we see that increase in atomic mass causes shorter periods of recurrence of bands, while we know that it causes greater periods in the recurrence of lines.

It is also worthy of remark that the most volatile of these elements emits a continuous spectrum, with a band spectrum just emerging from it; the second gives us a beautiful and purely a band spectrum, while the third least volatile and more metallic substance of largest atomic mass, and producing the densest vapour, yields a band spectrum, together with a line spectrum. Several metals, such as nickel, yield nothing but lines, others give us both lines and bands, as manganese and iron, while tin, lead, silver, and gold yield very beautiful band spectra. Metalloids and non-metallic elements are generally considered to be essentially different from metals, since they emit channelled or band spectra at one temperature and line spectra at another. It was, in fact, first laid down by Plücker and Hittorf that "*There is a certain number of elementary substances, which, when differently heated, furnish two kinds of spectra of quite a different character, not having any line or any band in common*" ('Phil. Trans.,' vol. 155, p. 6).

The discovery of this fact was of great importance, for it led to the conclusion that as one spectrum of an element is replaced by another and totally different spectrum of the same element, there must be an analogous change in the constitution of the ether, indicating a new arrangement of the gaseous molecules, and this implies either a chemical decomposition, or an allotropic condition of the vapour of the substance. Plücker and Hittorf concluded that the same matter, in two allotropic states, emitted different spectra, but the allotropy was dependent solely on temperature. Band spectra they designated spectra of the 1st Order, and Line spectra, spectra of the 2nd Order. The former have been fully recognized as the spectra of metalloids, such as carbon, phosphorus, sulphur, selenium, and tellurium, but it seems to have been overlooked that Plücker and Hittorf observed spectra of the 1st Order in the case of a few heavy metals, particularly lead and manganese. Metallic lead and its compounds were found to yield the same band spectrum in the oxy-hydrogen flame, and manganese exhibited a curious spectrum of the 1st Order, most similar to that of carbon, but with the lines composing the bands differently distributed. The well-known spark spectra of these elements are spectra of the 2nd Order.

Lecoq de Boisbaudran has observed a beautiful spectrum of aluminium of the

1st Order, obtained by means of an uncondensed spark. That this metal at so high a temperature yields such a spectrum is undoubtedly due to the fact that it is almost, if not absolutely, impossible to vaporize it with the oxy-hydrogen flame.*

Liveing and Dewar have recently obtained a band spectrum by the combustion of nickel tetracarbonyl which is also accompanied by lines ('Roy. Soc. Proc.,' vol. 52, p. 117). This spectrum, I expect, will be found to be due to metallic nickel and not to the compound substance.

Yttrium and scandium, in solutions of their chlorides, each yield a line spectrum, with a group of bands in the red and orange region, when submitted to the action of a condensed spark. From the foregoing facts, and from the descriptions of spectra which here follow, it will be seen that several metallic elements emit banded spectra.

*Characteristic Flame Spectra of Elements emitted at High Temperatures.*

I. *Line Spectra.*—Lithium, thallium, nickel, cobalt.
II. *Band Spectra.*—Antimony, bismuth, gold, tin, sulphur, selenium.
III. *Band Spectra with Lines.*—Copper, iron, manganese, tellurium, lead, and silver.
IV. *More or less continuous Spectra with Lines.*—Sodium, potassium, magnesium, chromium, cadmium.
V. *A continuous Spectrum.*—Zinc, carbon, arsenic, aluminium.
VI. *No Spectrum.*—Platinum.

It might be supposed that the band spectra were due to the oxides and not to the metallic elements in Group II., but there is evidence against this in the case of silver† and gold, since no oxides of these metals can exist at the temperature of the flame employed.

In the case of manganese the evidence is of a different character, and may be referred to at somewhat greater length, since Marshall Watts has attributed the band spectrum seen in the Bessemer flame to the oxide of manganese, chiefly on the ground that it was yielded by manganese chloride (*Spectres Lumineux*), and in the oxy-hydrogen flame by manganic oxide. No evidence was adduced to show that the spectrum in either instance was due to the metal.

* See Appendix 5, p. 211.

† [Channelled emission spectra of silver and tin, produced by the electric arc, have been noticed by Liveing and Dewar.

"Tin gives flutings in highly refrangible portions of the spectrum, and silver gives a fine fluted looking spectrum in the blue." 'Roy. Soc. Proc.,' vol. 34, p. 122, 1882.

The same observers have described the channelled spectrum of magnesium oxide. A set of seven bands in the green beginning λ 5006–4 and fading towards the violet side of the spectrum are stated to be due to the oxide or to the process of oxidation. 'Roy. Soc. Proc.,' vol. 44, p. 243.—W. N. H. September 29, 1893.]

On the other hand, the evidence that it is due to the metal is of the following character :—

(1.) It may be produced from the metal in a reducing flame, and it disappears when an excess of oxygen is present. (2.) Although it may be produced by heating manganic oxide containing 66 per cent. of manganese, the spectrum is weak. (3.) A stronger spectrum is obtained by heating spiegel-eisen containing 18 to 20 per cent. of manganese, and by heating ferro-manganese, containing 80 per cent. of manganese, than that which it is possible to obtain by heating, to the same temperature and during the same period, manganic oxide containing 66 per cent. of manganese. Silico-spiegel containing 10 per cent. of silicon and 18 to 20 per cent. of manganese did not yield the manganese bands so strongly as the spiegel-eisen containing the same proportion of metal, probably because the manganese is converted into silicate. Even TURTON'S tool steel yields a fairly strong indication of the manganese bands.

If we examine the spectrum of air of the first order as obtained by sparks uncondensed, it appears to consist of bands only, but a more minute examination of spectra taken with an instrument giving considerable dispersion and excellent definition has shown that the bands are composed of three over-lapping series of lines. Such a character is usual with degraded band spectra of elements. If the pressure be reduced from the normal of 760 millims. to something like 5 millims. or less, then the bands disappear, and the strongest edge of each band remains as a line to represent the spectrum of the element at diminished pressure. Now, this change is one which is observed in the case of those metals which give band spectra, but, if they give bands and lines together, then the lines remain after the bands have vanished. This is to be observed in the spectra of silver, lead, bismuth, and tellurium.

The most interesting case, however, is that of silver, for the spectrum is composed of a number of regularly disposed and closely placed lines.

The bands are degraded towards the rays of lesser refrangibility, that is to say, in this direction the lines are of diminishing intensity, and they are of increasing width apart. When the quantity of silver diminishes, and consequently the vapour exerts less pressure, being mixed with the vapour of other metals, the bands become narrower until at last nothing but lines remain, and these are the strongest lines belonging to the strongest bands. They correspond to those on the spark spectrum with wave-lengths 3382·3 and 3280·1.

Thus we see how the line spectra are related to band spectra, and that there is really no essential difference between the constitution of the matter which enters into the vapours of metals and metalloids; there is, in fact, something in their constitution common to both, which is apparently dependent on their vapour pressures and probably due to the action of the molecules upon one another when

their mean path is so extended that their motions become rhythmical. Reduce the freedom of their motions and the result is a continuous spectrum.*

MITSCHERLICH first drew attention to the distinct spectra, for the most part composed of bands, which are emitted by compounds ('POGG. Annalen.,' vol. 121, p. 459).

DIACON also ('Thèses de Physique et de Chimie,' Montpellier, 1864, Boehm et fils), using a flame the interior of which was fed with chlorine, obtained distinct spectra of chlorides such as those of the alkaline earths, also gold, lead, iron, cobalt, and nickel.

The alkalies gave no spectrum except where the conditions were such that they became converted into oxide or metal, as in the mantle of the flame. Of the various compounds examined, some gave degraded band spectra, others plain bands, and many yielded line spectra, or bands and lines together. PLÜCKER and HITTORF first showed that the alkali metals and their salts emit, even at a low temperature, spectra of the 2nd Order or lines, while metals of the alkaline earths, and compounds of the same emit band spectra, accompanied by a principal line. When the bands are well developed they constitute a spectrum of the 1st Order; this was proved in every respect to be the case with the band spectrum of barium.

### *Flame Spectra Emitted by Compounds at High Temperatures.*

I. *Spectra of Elements. Chiefly Lines.*—Iron, nickel, cobalt, chromium, manganese, sodium, potassium, lithium, thallium, rubidium.

II. *Spectra Peculiar to Compounds. Lines and Bands together.*—Calcium oxide and salts, calcium fluoride, strontium oxide and salts, barium oxide and salts, beryllium oxide and salts, magnesium oxide and salts, aluminium oxide and salts, cadmium oxide and salts, copper oxide and salts, chromic trioxide, phosphorus pentoxide, cerium oxide and salts, cerium chloride.

The study of the spectra of compounds is one of much interest, particularly in its bearings on the periodic law, and the prosecution of this subject is being continued.

### *Application of the Oxy-hydrogen Flame Spectra to Chemical Analysis.*

*Alkali Metals.*—The examination of insoluble minerals, such as silicates, in order to detect the alkali metals, may be readily made with the oxy-hydrogen blow-pipe. Proof of the presence of lithium and sodium in kyanite is evidence of this. My assistant, Mr. RAMAGE, examined a microcline felspar from the granite of Dalkey, Co. Dublin, by fixing a piece of it in the flame for half-an-hour while a photograph was taken. The lines of sodium, potassium, lithium, and rubidium were identified.

*Alkaline Earth Metals.*—A piece of dolomite gave the lines and bands characteristic

* See Professor SCHUSTER'S British Association Report, 1880.

of lime with the bands of magnesium. The sulphates of calcium, strontium, and barium readily yield their spectra by exposure to the flame.

*Metals Yielding Band Spectra.*—These are elements of considerable volatility, the lines of which become converted into bands as their proportion in the substances to be examined diminishes.

The lines which serve for the detection of small quantities of the respective elements are the following :—

| | λ. | |
|---|---|---|
| Copper | 3273·2<br>3246·9 | |
| Silver | 3382·3<br>3280·1 | |
| Tin | 3033·1<br>3007·9 | |
| Lead | 4059 | Mean of {4061·5 / 4057·6} |
| | 3684 | Or (3682·9) |
| | 3639·5 | (3639·2) |
| | 2832·2 | |
| Thallium | (5349·6)<br>3775·6 | |
| Bismuth | 4724·5<br>3067·0 | Approximately |
| Cadmium | (3261·17) | |
| Manganese bands | {5845 to 5700 / 5700 „ 5645 / 5645 „ 5591} | |
| „ lines | (4031·8)<br>(4029·9) | These lines are visible after the bands have disappeared most completely |

As an illustration of the method of testing for these substances it may be mentioned that a finely crystallized specimen of bismuth was volatilized in the flame. A number of conspicuous lines on the photograph were measured with the ivory scale and their wave-lengths ascertained. Thus two lines were identified with thallium, three with lead, two with copper, two with silver, and the remainder proved to be bismuth lines. Copper was detected in steel.

*Metals which emit Line Spectra.*—The spectra of these elements are somewhat complicated, taking for instance iron, nickel, and cobalt, as examples. Iron is readily

detected by the groups of lines lying between 3929·7 and 3749·4, also between 3745·4 and 3683. Chromium is recognized by its two sets of triplets. A more particular examination of nickel and cobalt has not yet been made with a view of ascertaining their most persistent lines.

The prominent manganese lines were detected in the spectra obtained from malleable cobalt and nickel, also in fine steel.

## *Descriptions of Spectra and Measurements of Lines and Bands, with their approximate Wave-lengths.*

### The Oxy-Coal-Gas Flame.

The flame was non-luminous. Photographs were taken with a somewhat wide slit, and the exposure was one hour. The edges of the bands are as sharp as they are generally seen in the spectrum of a Bunsen flame, and the lines of which the bands are composed are somewhat wide. No attempt was made to purify the coal-gas, as the object of examining this spectrum was to determine the origin of any lines which might be caused by hydrocarbons in the oxy-hydrogen flame. Lecoq de Boisbaudran has carefully described variations in the spectrum seen under different circumstances in the flame of a Bunsen burner, but there is no occasion to refer to these further. (*Spectres Lumineux.*)

All the principal bands observed are probably due partly to carbon and partly to what is generally considered as the cyanogen spectrum. They are indicated by (C) carbon, and $(CN)_2$ cyanogen. The measurements of lines and bands made by other authors are indicated thus:—K. and R., Kayser and Runge; L., Lecoq de Boisbaudran; L. and D., Liveing and Dewar; D., Deslandres; W., Watts; F., Fievez. The lines and bands were all measured twice and their wave-lengths ascertained on two separate occasions. $\beta$, $\gamma$, $\delta$, $\epsilon$ are groups or bands described by Lecoq de Boisbaudran.

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## The Oxy-Coal-Gas Flame.

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 26·02 | The fainter edge of the 1st band | 17671·5 | 5659 | |
| 26·92 | „ stronger „ „ „ | 17775·5 | 5627 | 5627·5 (C), F. |
| 27·32 | The fainter edge of the 2nd band | 17821 | 5611 | 5610·8 (C), F. |
| 28·33 | „ stronger „ „ „ | 17938 | 5577 | 5577·7, 5577·4, 5577·0 (C), F. |
| 28·82 | The fainter edge of the 3rd band | 17993·6 | 5557 | 5557 (C), F. |
| 29·93 | „ stronger „ „ „ | 18119·2 | 5520 | This is the $\delta$ group described by Lecoq de Boisbaudran. Yellow rays. |
| 30·72 | The stronger edge of the 4th band overlapped by the foregoing ($\delta$) | 18207 | 5492 | |
| 31·31 | „ „ „ 5th „ „ „ „ | 18272 | 5473 | 5478·4 (C), W. |
| 32·1 | „ „ „ 6th „ „ „ „ | 18360·5 | 5446 | 5440 (C), W. |
| 32·88 | „ „ „ 7th „ „ „ „ | 18447 | 5422 | 5425 (C), W. |
| 33·54 | „ „ „ 8th „ „ „ „ | 18521 | 5399 | |
| 34·38 | „ „ „ 9th „ „ „ „ | 18614 | 5372 | |
| 40·45 | The less refrangible edge of the 10th band | 19257·5 | 5193 | |
| 41·21 | „ more „ „ „ „ | 19341·5 | 5170 | 5165·5 (C), W. |
| 42·32 | A marking like the darker edge of the 11th band | 19463·2 | 5138 | 5138·56, 5138·34, 5138·13 (C), K. and R.; 5138·4, F. |
| 43·68 | „ „ „ „ 12th „ | 19613 | 5098 | 5097·9, F.; 5100, W. 5098·34, 5098·19 (C), K. and R. |
| 47·0 | „ „ „ „ 13th „ | 19962 | 5086 | 5086·9 (C), F.; 5082 (C), W. 5086·43, 5086·31 (C), K. and R. |
| 49·2 | The darker edge of a faint band overlapped by foregoing (14th) | 20192·2 | 4952 | 4951·5 (C), K. and R. |
| 51·35 | The less refrangible edge of a broad band (15th) | 20415 | 4899 | 4899·98 (C), K. and R. |
| 54·7 | Marking in of a broad band | 20762·5 | 4816 | 4815·66 (C), K. and R. |
| 56·47 | | 20946·5 | 4774 | 4775·32 (C), K. and R. |
| 56·89 | The more refrangible edge of the same | 20989·5 | 4765 | 4763·86 (C), K. and R. |
| | A band is overlapped by this. | | | |

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## The Oxy-Coal-Gas Flame—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | | $\frac{1}{\lambda}$. | λ. | Remarks. |
|---|---|---|---|---|---|
| 57·765 | This is the stronger portion of the γ group described by Lecoq de Boisbaudran. Markings like sharp lines in the 16th band | γ | 21081 | 4743·5 | 4739·8 (C), W.<br>4731·9 (C), F. |
| 58·24 | | | 21130·2 | 4732 | 4732·33 (C), K. and R.<br>4731·93 (C), K. and R. |
| 58·79 | | | 21187 | 4720 | 4719·87 (C), K. and R.<br>4720·1 (C), F.; 4717·2 (C), W. |
| 59·56 | | | 21267 | 4702 | 4702·3 (C), K. and R.<br>4702 (C), F.; 4698·4 (C), W. |
| 60·22 | The stronger or more refrangible edge of the same . . . . . | | 21335 | 4688 | 4688·2 (C), K. and R.<br>4688·9 (C), F.; 4684·2 (C), W. |
| | This band also overlaps another diffused band. | | | | |
| 60·56 | Markings in the 17th band. This is the weaker part of the γ group. | | 21370 | 4679 | 4678·9 (C), F.; 4677 (C), W.<br>4679 (C), W. |
| 60·91 | | | 21405 | 4672 | 4672·2 (C), F.; 4675 (C), L. |
| 71·0 | Stronger edge of the same . . . . . | | 22414 | 4462 | |
| 74·0 | The edge of a marking like a broad band or a continuous spectrum, very diffused (18th band) | | 22709 | 4405 | |
| 74·485 | Markings like lines in the 18th band . . . . . | | 22754 | 4395 | |
| 75·49 | | ε | 22847·2 | 4378 | 4381 (C), L. and D.<br>About the centre 4368 (C), L. |
| 76·22 | The stronger and more refrangible edge of the same . . . . . | | 22916·8 | 4364 | 4365 (C), L. and D. |
| 76·95 | The stronger edge of a fainter band overlapped by the foregoing . . . | | 22985 | 4350 | |
| 77·51 | A faint though sharp line . . . . . | | 23035 | 4342 | |
| 78·085 | The sharp, less refrangible edge of a strong broad line merging into a band or continuous spectrum | | 23086·4 | 4332 | |
| 79·305 | Probably the more refrangible edge of the same line, or may be only a marking in the above band or continuous spectrum | β | 23194 | 4312 | 4311 (C), W. |
| 79·86 | Broad line in the continuous spectrum or band . . . . . | | 23246 | 4302 | |
| 80·68 | ,, ,, ,, ,, ,, . . . . . | | 23322·2 | 4288 | |
| 81·07 | ,, ,, ,, ,, ,, . . . . . | | 23358·5 | 4282 | |
| 81·52 | ,, ,, ,, ,, ,, . . . . . | | 23400 | 4273 | |
| 81·95 | ,, ,, ,, ,, ,, . . . . . | | 23436 | 4268 | |
| 82·3 | ,, ,, ,, ,, ,, . . . . . | | 23472·5 | 4260 | |

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## The Oxy-Coal-Gas Flame—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 82·61 | Marking in the continuous spectrum, or band | 23501 | 4255 | |
| 83·1 | „ „ „ „ | 23547 | 4248 | |
| 83·56 | „ „ „ „ | 23589·5 | 4240 | |
| 84·21 | „ „ „ „ | 23649·5 | 4230 | |
| 85·0 | „ „ „ „ | 23722 | 4215 | 4215·26 $(CN)_2$ K. and R. |
| 85·57 | „ „ „ „ | 23773·5 | 4208 | 4208·4 $(CN)_2$ K. and R. |
| 86·25 | „ „ „ „ | 23836 | 4196 | 4196·05 $(CN)_2$ K. and R. |
| | There were several other lines which were too faint to measure with a magnifying power of 10 diams. | | | |
| | Then appears a series of beautiful very fine and closely adjacent lines, numbering sixteen in all. | | | |
| 99·22 | First line of the series | 24985 | 4003 | |
| 99·6 | Second „ „ | 25012 | 3998 | |
| 100·05 | Third „ „ | 25052 | 3992 | |
| 100·64 | Fourth „ „ | 25104·6 | 3984 | |
| 101·44 | Fifth „ „ | 25176·5 | 3973 | |
| 102·135 | Sixth „ „ | 25236·2 | 3963 | |
| 102·88 | Seventh „ „ | 25298 | 3954 | |
| 103·36 | Eighth „ „ | 25341 | 3946 | |
| 103·96 | Ninth „ „ | 25391·3 | 3938 | |
| 104·45 | Tenth „ „ | 25432·5 | 3932 | |
| 104·9 | Eleventh „ „ | 25470·4 | 3926 | |
| 105·46 | Twelfth „ „ | 25516·2 | 3920 | 3920·6 (C) D. |
| 105·8 | Thirteenth „ „ | 25545 | 3913 | |
| 106·2 | Fourteenth „ „ | 25579 | 3908 | |
| 106·61 | Fifteenth „ „ | 25613·5 | 3904 | |
| 107·06 | Sixteenth „ „ | 25652 | 3898 | |
| 107·5 | Less refrangible edge of a broad line or narrow dark band | 25689·4 | 3893 | 3893·1 (C), D. |
| 108·35 | More „ „ „ „ „ „ „ | 25761·5 | 3882 | 3883·1 $(CN)_2$, D. |

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THE OXY-COAL-GAS FLAME—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 109·45 | Faint line or less refrangible edge of a faint band . . . . . | 25855·5 | 3868 | 3871·4 $(CN)_2$, D. |
| 110·48 | ,, ,, ,, marking in the same . . . . . | 25932·2 | 3856 | 3855·06 $(CN)_2$, K. and R. 3854·7 $(CN)_2$, K. and R. |
| 111·17 | ,, ,, ,, ,, ,, ,, . . . . . | 26001·5 | 3846 | |
| 111·63 | ,, ,, ,, ,, ,, ,, . . . . . | 26040·4 | 3840 | 3839·98 $(CN)_2$, K. and R. |
| 112·32 | ,, ,, ,, ,, ,, ,, . . . . . | 26100 | 3831 | 3831·15 $(CN)_2$, K. and R. |
| 112·81 | ,, ,, ,, ,, ,, ,, . . . . . | 26141·3 | 3825·5 | 3825·4 $(CN)_2$, K. and R. 3825·1 (C), D. |
| 113·0 | ,, ,, ,, ,, ,, ,, . . . . . | 26157·8 | 3823 | 3823·9 $(CN)_2$, K. and R. |
| 113·45 | ,, ,, ,, more refrangible edge of the same band . . . . . | 26190·5 | 3818·3 | 3819·36 $(CN)_2$, K. and R. |
| 113·78 | Less refrangible edge of a faint band . . . . . | 26214·2 | 3815 | 3816·24 $(CN)_2$, K. and R. |
| 115·8 | More ,, ,, ,, the same . . . . . | 26386 | 3790 | |
| 128·74 | Less refrangible edge of a faint band . . . . . | 27455 | 3642·5 | 3642·63 $(CN)_2$, K. and R. |
| 134·81 | More ,, ,, ,, the same . . . . . | 27943 | 3579·5 | 3579·22 $(CN)_2$, K. and R. |
| 135·79 | Two faint lines, like markings in or edges of bands . . . . . | 28022 | 3568·5 | 3568·4 $(CN)_2$, K. and R. |
| 136·37 | | 28067 | 3563 | 3563·92 $(CN)_2$, K. and R. |
| 138·28 | A faint line, like a marking in or edge of a band . . . . . | 28212 | 3544·5 | 3545·07 $(CN)_2$, K. and R. |
| 140·0 | ,, ,, ,, ,, ,, ,, ,, ,, . . . . . | 28343 | 3528 | 3528·71 $(CN)_2$, K. and R. |
| 140·65 | ,, ,, ,, ,, ,, ,, ,, ,, . . . . . | 28392·8 | 3522 | 3522·49 $(CN)_2$, K. and R. |
| 143·17 | ,, ,, ,, ,, ,, ,, ,, ,, . . . . . | 28584 | 3498·5 | 3497·7 $(CN)_2$, K. and R. |
| 144·33 | ,, ,, ,, ,, ,, ,, ,, ,, . . . . . | 28672·5 | 3487·8 | 3487·61 $(CN)_2$, K. and R. |
| 145·29 | ,, ,, ,, ,, ,, ,, ,, ,, . . . . . | 28746 | 3478·8 | |
| 145·84 | ,, ,, ,, ,, ,, ,, ,, ,, . . . . . | 28788 | 3473·6 | |
| 148·21 | A group of five closely adjacent, very fine faint lines . . . . . | 28969 | 3452 | |
| 148·62 | | 29001 | 3448 | |
| 148·91 | | 29022·5 | 3445 | |
| 149·42 | | 29062 | 3441 | |
| 149·79 | A faint line . . . . . | 29090 | 3437 | |
| 153·82 | ,, ,, . . . . . | 29395 | 3402 | |
| 154·71 | ,, ,, . . . . . | 29461·5 | 3394 | |
| 155·9 | ,, ,, . . . . . | 29551 | 3384 | |
| 157·09 | ,, ,, . . . . . | 29640 | 3373 | |
| 158·86 | ,, ,, . . . . . | 29771·5 | 3359 | 3360·1 $(CN)_2$, D. |
| 160·145 | ,, ,, . . . . . | 29866 | 3349 | |
| 161·62 | ,, ,, . . . . . | 29975·5 | 3336·5 | |

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THE OXY-COAL-GAS FLAME—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 162·43 | A faint line | 30035·5 | 3330 | |
| 163·48 | ,, ,, | 30112·5 | 3321 | |
| 164·47 | ,, ,, | 30186·5 | 3313 | |
| 165·55 | ,, ,, | 30266·5 | 3304 | 3305·3 (C), D. |
| 166·17 | ,, ,, | 30312·5 | 3299 | |
| 167·5 | ,, ,, | 30411 | 3288 | |
| 168·72 | ,, ,, | 30501 | 3278 | |
| 170·0 | ,, ,, | 30595 | 3269 | |
| 171·65 | ,, ,, | 30717 | 3256 | |
| | There are a few more of these lines, which, however, were too faint to measure accurately with a magnifying power of ten diameters. | | | |

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## The Carbon Monoxide Flame.

The gas was burnt from a blow-pipe along with oxygen. The plate was exposed for one hour. The spectrum is continuous from about λ 5800 to about λ 3000.

A somewhat wide slit was used as in photographing the oxy-coal-gas flame.

Certain broad lines occur on the continuous rays, and these for the most part have been identified with certain lines occurring in the spectrum of carbon, as the measurements approximate closely to some of those taken from the spectra of this element observed by Marshall Watts, Ångström and Thalén, and Piazzi Smyth.

The very strong and extended continuous spectrum is a remarkable feature of this, as it is likewise in that of the Bessemer flame spectrum.

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | λ. | Remarks. |
|---|---|---|---|---|
| 9·7 | A faint line or band, marking scarcely visible, not sharp but indistinct . | 15782 | 6337 | |
| 13·5 | ,, ,, ,, ,, ,, ,, ,, . | 16208 | 6172 | |
| 18·75 | ,, ,, ,, ,, ,, ,, ,, . | 16822 | 5945 | 5953·5 (C), Å. and T.; 5955 (C), W. |
| 23·0 | An exceedingly faint line . . . . . | 17318 | 5777 | |
| 29·5 | A faint line . . . . . | 18070 | 5534 | 5534·5 (C), Å. and T. |
| 31·3 | ,, ,, . . . . . | 18271 | 5473 | 5473 (C), P. S. |
| 41·3 | ,, ,, . . . . . | 19352 | 5168 | 5165·5 (C), W. |
| 46·0 | A very faint line or band marking, just barely an indication that there is an inequality in the continuous spectrum. This same description applies to all that follows | 19857 | 5037 | 5036·7 (C), Å. and T. |
| 48·5 | ,, ,, ,, ,, ,, ,, ,, | 20119 | 4970·5 | 4969 (C), Å. and T., band; also line, W. |
| 49·5 | ,, ,, ,, ,, ,, ,, ,, | 20223 | 4945 | 4947 (C), line, W. |
| 62·5 | ,, ,, ,, ,, ,, ,, ,, | 21555·5 | 4640 | 4637 (C), line, W. |
| 64·75 | ,, ,, ,, ,, ,, ,, ,, | 21790 | 4589 | 4585 (C), line, W. |
| 71·8 | ,, ,, ,, ,, ,, ,, ,, | 22494 | 4446 | |
| 83·0 | ,, ,, ,, ,, ,, ,, ,, | 23537·5 | 4249 | 4249 (C), band, W. |
| 84·5 | ,, ,, ,, ,, ,, ,, ,, | 23676 | 4224·5 | |
| 87·0 | ,, ,, ,, ,, ,, ,, ,, | 23904·5 | 4183 | |

## Lithium.

Lithium chloride. Exposure 30 minutes. Kayser and Runge's measurements refer to arc spectra of the alkalies and alkaline earths. 'Ueber die Spectren der Elemente,' Königl. Preuss. Akademie, 1890, IV.

| Ivory scale numbers. | $\frac{1}{\lambda}$ | Kayser and Runge's measurements. | | |
|---|---|---|---|---|
| | | $\frac{1}{\lambda}$ | $\lambda$. | |
| 2·8 | .. | 1490713 | 6708·2 | P.s. |
| 64·1 | 2173 | 2172794 | 4602·37 | D.s. |
| 90·3 | 2420 | 2419878 | 4132·44 | D.s. |
| 174·55 | 3094 | 3093322 | 3232·77 | P.s. |

P.s. Principal series.
D.s. Diffuse series.

## Sodium.

Sodium chloride. A perfectly pure specimen specially prepared. Exposure 35 minutes. A very strong continuous spectrum extends from λ6020 to 3600, it continues weakly to λ3320. *Loc. cit.*, Kayser and Runge.

| Ivory scale numbers. | $\frac{1}{\lambda}$ | $\lambda$. | Kayser and Runge's measurements. | | Remarks. |
|---|---|---|---|---|---|
| | | | $\frac{1}{\lambda}$ | $\lambda$. | |
| 6·0 | 15340 | 6518 | .. | .. | Bands and lines not previously observed. Some rather broad, others narrow. |
| 8·0 | 15574 | 6420 | .. | .. | |
| 9·5 | 15748 | 6349 | .. | .. | |
| 10·8 | 15898 | 6290 | .. | .. | Band with lines upon it. |
| 11·2 | 15946 | 6271 | .. | .. | |
| 12·3 | 16042 | 6233 | .. | .. | Stronger edge of band. |
| 14·2 | 16290 | 6138 | .. | .. | Stronger edge of band at 15·81. |
| 16·8 | 16595 | 6026 | .. | .. | Centre of band with stronger edge at 17·25. |
| 20·0 | 16975 | .. | 1696091<br>1697738 | 5896·16<br>5890·19 | $D^1$ P.s.<br>D |
| 25·3 | 17575 | .. | 1758007<br>1759665 | 5688·26<br>5682·9 | D.s. |
| 47·8 | 2007 | .. | 2006610<br>2008314 | 4983·5<br>4979·3 | D.s. |
| 61·1 | 2142 | .. | 2141603<br>2143531 | 4669·4<br>4665·2 | D.s. |
| 165·6 | 30280 | .. | 3027487<br>3028037 | 3303·07<br>3302·47 | P.s. |

P.s. Principal series.
D.s. Diffuse series.

## Potassium.

Potassium chloride. Exposure 25 minutes. A very strong continuous spectrum extends from λ 4610 to 3440, continuing more weakly to 3057, *loc. cit.*, Kayser and Runge.

| Ivory scale-numbers. | $\frac{1}{\lambda}$ | Kayser and Runge. | | Remarks. |
|---|---|---|---|---|
| | | $\frac{1}{\lambda}$ | λ | |
| 21·1 | 1714 | 1714610 | 5832·23 | S.s. * |
| 22·3 | 1723 | 1723541 | 5802·01 | D.s. B group |
| 22·8 | 1729 | 1729305 | 5782·67 | D.s. L. de B. |
| 34·9 | 1866 | 1865713 | 5353·6 | S.s. Measured also by |
| 35·4 | 1873 | 1872631 | 5340·08 | S.s. L. de B. |
| 96·15 | 2471 | 2470746 | 4047·36 | P.s. Measured also by |
| 96·3 | 2473 | 2472622 | 4044·29 | P.s. L. de B. |
| 148·7 | 2902 | (2900661 2901503) | (3447·49 3446·49) | P.s. |
| 176·7 | 3110 | 31080 | (3217·76 3217·27) | P.s. |

P.s. Principal series.
D.s. Diffuse series.
S.s. Sharp series.

## Cadmium.

Metal and also cadmium sulphate yield the same spectrum, consisting of one line only. It is the least refrangible of the triplets at Cd 17. Exposure 30 minutes.

| Scale-numbers. | Oscillation frequencies from curve. | Oscillation frequencies for comparison. | Wave-lengths. | |
|---|---|---|---|---|
| 170·9 | 30663 | 3066384 K. and R. | 3261·17 K. and R. | Kayser and Runge. |

## Zinc and Zinc Oxide.

Zinc foil was burnt in the oxy-hydrogen flame during 30 minutes. Nothing but a continuous spectrum is visible. Zinc oxide was intensely ignited in the flame for 60 minutes; it yielded nothing but a continuous spectrum. No lines or bands were visible.

* Measured also by Lecoq de Boisbaudran.

## Calcium Fluoride.

The substance used was fluor spar. Exposure 40 minutes.

| Ivory scale-numbers. | $\frac{1}{\lambda}$ | $\lambda$ | Remarks. |
|---|---|---|---|
| 12·5 | 16094 | 6213·5 | The centre of a band |
| 17·2 | 16642 | 6009 | ,, ,, ,, |
| 24 to | 17425 | 5739 | A faint band |
| 28·2 | 17910 | 5583·5 | |
| 28·2 to | 17910 | 5583·5 | Band stronger than the preceding |
| 30·5 | 18171 | 5503 | |
| 35·15 to | 18683 | 5352·5 | Band |
| 36·3 | 18812 | 5316 | |
| 36·3 | 18812 | 5316 | Band |
| 36·7 | 18855 | 5303·5 | |
| 84·35 | 23637 | 4231 | A strong line. |

The last is possibly a line measured in the calcium spectrum by Kayser and Runge $\lambda$ 4226·91. 'Ueber die Spectren der Elemente,' Königl. Preuss. Akademie, 1891, IV.

## Strontium Oxide.

Strontium sulphate was the substance used. Exposure 30 minutes.

| Ivory scale numbers. | $\frac{1}{\lambda}$ | $\frac{1}{\lambda}$ | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 15·4 to | 16434 | | 6085 | A band. |
| 16·3 | 16520 | | 6053 | |
| 21·9 | | | | Weak line. |
| 29·2 | 18028 | 1803918* | *5543·49 | Weak nebulous line. |
| 63·8 | 21697 | 2170365* | *4607·52 | Strong line. |
| 64·8 | 21780 | | 4591 | Faint. Sr? |
| 84·25 | 23650 | 2365794* | *4226·91 | Faint. |
| 85·0 | 23700 | | 4216·5 | Faint. |
| 93·9 | 24517 | 2452254* | *4077·88 | |

* Lines measured by Kayser and Runge. 'Ueber die Spectren der Elemente,' Königl. Preuss. Akademie, 1891, IV.

## Barium Oxide.

### Barium Sulphate. Exposure 30 minutes.

| Ivory scale numbers. | $\frac{1}{\lambda}$ | $\lambda$ | Remarks. |
|---|---|---|---|
| 24·5 to | 17483 | 5720 | The centre of a weak band. |
| | 17508 mean | 5712 | |
| 25 | 17551 | 5697 | |
| 25·3 to | 17575 | 5690 | A strong band overlapping a weak one. |
| 26·1 continues to | 17667 | 5660 | |
| 27·2 | 17795 | 5619·5 | |
| 28·0 to | 17900 | 5587 | A band which is weakened between 28·9 and 30·9. |
| 28·9 continues to | 18002 | 5555 | |
| 30·5 | 18183 | 5499 | A line lies on the preceding P.s. band. |
| 29·3 | 18037 | 5544 | |
| 30·5 | 18170 | 5503 | End of band, sharp. |
| 34·0 to | 18572 | 5384 | |
| 35·0 | 18670 | 5356 | End of band, sharp. |
| 36·0 to | 18789 | 5322 | |
| 39·5 | 19154 | 5221 | End of band, sharp. |
| 41·5 to | 19373 | 5162 | Band. |
| 44·0 | 19648 | 5089·5 | |
| 50 to about 54 | 20275 | 4932 | |
| 51·8 to | 20463 | 4887 | Stronger part of band. |
| 52·8 | 20565 | 4862·5 | |
| 54·0 | 20690 | 4833 | |
| 59 to | 21208 | 4715 | Very faint band. |
| 60 | 21312 | 4692 | |

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## Magnesium Oxide.

The bands of magnesia are remarkably distinct and strong, lying between λ 3980 and 3680. The more refrangible of the two strongest and principal bands is the broader, and in a marked manner it is degraded towards the less refrangible side. With a plate exposed 30 minutes, magnesium sulphate yields a very strong spectrum, which in parts is too dense to show the details in the bands to advantage. A specimen of dolomite showed the spectrum extremely well.

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$ | λ. | Remarks. |
|---|---|---|---|---|
| 104·71 | The less refrangible edge of strong band degraded towards the less refrangible side. | 25454 | 3929 | Liveing and Dewar have investigated the spectrum of MgO in $OH_2$ flame. See appendix, p. 210. |
| 108·32 | Flutings or markings on this band . . . . . | 25759 | 3883 | |
| 108·94 | ,, ,, ,, . . . . . | 25812 | 3874 | |
| 110·41 | The more refrangible edge . . . . . | 25936 | 3856 | |
| 111·43 | A strong line . . . . . | 25962 | 3852 | |
| 112·16 | The less refrangible edge of a well-marked band, very strong; the edge is marked by a line. There is another similar line at 114·52. | 26081 | 3834 | |
| 114·52 | More refrangible edge of band, which overlaps the next succeeding band. | 26276 | 3805 | |
| | From 114·52 up to 126 there is a very fine band, strongly degraded towards the less refrangible side. It is composed of a number of lines, or very narrow, but rather diffuse, bands, which are closer together as they become more refrangible. It was impossible to measure these component lines throughout the spectrum. | | | |
| 114·52 | The band, less refrangible edge visible . . . . . | 26276 | 3805 | |
| 120·0 | A line or narrow band in same . . . . . | 26741 | 3739 | |
| 120·55 | A fairly strong line or band in same . . . . . | 26788 | 3733 | |
| 122·6 | A stronger line or band in same . . . . . | 26923 | 3714 | |
| 122·6 | A strong line or band in same . . . . . | 26958 | 3709 | |
| 125·1 | The more refrangible edge of this strong band, which appears to be degraded also on the more refrangible side, or it overlaps another band. | 27159 | 3682 | |
| | A shading or diffused band of rays extends from 125 to 135, with a stronger portion about 130. | | | |
| 236·32 | A very strong, well-defined line . . . . . | 35060 | 2852 | Arc and spark 2852·22. Kayser and Runge. |

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## Calcium Oxide.

These measurements are taken from dolomite and from pure lime.

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$ | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 11·33 | The less refrangible edge of a strong band gradually fading on its more refrangible side | 15992 | 6253 | |
| 14·76 | The more refrangible of the same . . . . . | 16355 | 6116 | |
| 15·72 | The less refrangible edge of a weaker band, the more refrangible edge of which is coincident with the sodium line at 20, though the band is strong only as far as 18 . . . . . | 16467 | 6075 | |
| 20·0 | The sodium line lies upon a band of continuous rays . . . . . | 16969 | 5895 | |
| 23 95 | The less refrangible edge of a stronger band lying upon the foregoing | 17429 | 5739 | |
| 27·72 | The less refrangible edge of an exceedingly strong band which lies upon, or is continuous with, the foregoing | 17867 | 5598 | A strong Ca line in arc, 5594·64. K. and R. |
| 31·0 | The more refrangible edge of the same . . . . . | 18238 | 5485 | |
| 32·17 | The less refrangible edge of weak band of continuous rays . . . . | 18368 | 5445 | |
| 32·87 | A marking in the same not very distinct . . . . . | 18445 | 5422 | |
| 33·8 | ,, ,, ,, ,, ,, . . . . . | 18550 | 5390 | |
| 34·85 | ,, ,, ,, ,, ,, . . . . . | 18665 | 5359 | |
| 35·42 | ,, ,, ,, ,, ,, . . . . . | 18729 | 5341 | |
| 36·06 | ,, ,, ,, ,, ,, . . . . . | 18796 | 5322 | |
| 36·64 | The more refrangible edge . . . . . This band is faint and becomes almost imperceptible when magnified ten diameters. | 18857 | 5304 | |
| 84·63 | The less refrangible edge of a very narrow band like a very strong broad line | 23688 | 4222 | 4226·91 Ca line, r. in arc, very strong. K. and R. |
| 85·2 | The more refrangible edge of same . . . . . | 23724 | 4215 | |

## Phosphorus Pentoxide.

A strong continuous spectrum extends from near the yellow sodium line to about λ 4090. A number of lines were observed many of which were identified with those of iron at wave-lengths 3888·2, 3860·5, 3749·4, 3747·6, 3736·9, 3733·5, 3722·8, 3720·2, 3705·5, 3440·2, and 3431·1. The following lines, all very faint, were not identified with any other substance, and it is probable that they are indications of a feeble band spectrum.

| Ivory scale-numbers. | λ. |
|---|---|
| 168·5 | 3279 |
| 169·2 | 3274 |
| 169·7 | 3271 |
| 170·05 | 3268 |
| 171·6 | 3255 |
| 172·9 | 3245 |

## Arsenic.

This element gave a faint nebulous line at 168·4 or λ 3280, which approximates the first line in the $P_2O_5$ spectrum.



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## SELENIUM.

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$ | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 51·68 | The fainter edge of a band | 20449·5 | 4890 | |
| 54·71 | The stronger edge of the same | 20763·5 | 4816 | |
| 55·22 | The fainter edge of a band | 20817 | 4804 | |
| 57·66 | The stronger edge of the same | 21070·5 | 4746 | 4745, SALET (spark), 475 by combustion. |
| 58·78 | The fainter edge of a band | 21186 | 4720 | |
| 60·73 | The stronger edge of the same | 21387 | 4676 | 4675 (PLÜCKER and HITTORF), spark. Also SALET. |
| 62·20 | The fainter edge of a band | 21535 | 4643 | |
| 64·28 | The stronger edge of the same | 21744 | 4599 | |
| 65·70 | The fainter edge of a band | 21884·6 | 4569·5 | |
| 69·50 | The stronger edge of the same | 22264·4 | 4491·5 | |
| | Here follow a series of 18 bands, which appear to overlap. | | | |
| 73·78 | The stronger edge of the 1st band | 22688 | 4407·5 | |
| 77·65 | ,, ,, 2nd ,, | 23048 | 4339 | |
| 80·01 | ,, ,, 3rd ,, | 23259·5 | 4299 | |
| 84·58 | ,, ,, 4th ,, | 23683·5 | 4222 | |
| 87·78 | ,, ,, 5th ,, | 23976·5 | 4170·5 | |
| 90·75 | ,, ,, 6th ,, | 24249·2 | 4124 | |
| 92·99 | ,, ,, 7th ,, | 24433 | 4093 | |
| 96·55 | ,, ,, 8th ,, | 24745 | 4041 | |
| 101·12 | ,, ,, 9th ,, | 25148·2 | 3976·5 | |
| 103·72 | ,, ,, 10th ,, | 25371·5 | 3941·5 | |
| 105·35 | ,, ,, 11th ,, | 25507·5 | 3921·5 | |
| 108·23 | ,, ,, 12th ,, | 25751·5 | 3883 | |
| 110·75 | ,, ,, 13th ,, | 25965 | 3851 | |
| 112·75 | ,, ,, 14th ,, | 26129·5 | 3827 | |
| 115·29 | ,, ,, 15th ,, | 26342·8 | 3796 | |
| 119·18 | ,, ,, 16th ,, | 26672 | 3749 | |
| 120·55 | ,, ,, 17th ,, | 26788 | 3733 | |
| 123·15 | ,, ,, 18th ,, | 27002 | 3707 | |

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## Tellurium.

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | λ. | Remarks. |
|---|---|---|---|---|
| 54·63 | Marking, like the edge of a faint band | 20755 | 4818 | 4820. A band, Salet. |
| 57·0 | ,, ,, ,, stronger band than the foregoing | 21007 | 4760 | 4767. ,, ,, |
| 59·54 | ,, ,, ,, ,, ,, ,, ,, | 21264·5 | 4702·5 | |
| 61·06 | ,, ,, ,, narrow band | 21420·5 | 4668·5 | 4670. ,, ,, |
| 62·0 | ,, ,, ,, ,, ,, | 21516 | 4648 | |
| 63·25 | ,, ,, ,, ,, ,, | 21641 | 4620·5 | |
| 64·56 | ,, ,, ,, ,, ,, | 21771 | 4593 | |
| 65·2 | ,, ,, ,, ,, ,, | 21835 | 4580 | |
| 67·4 | The stronger edge of a band | 22054·5 | 4532 | |
| 69·32 | ,, ,, ,, | 22246 | 4495 | |
| 70·57 | The fainter edge of a band | 22371 | 4470 | 4470. ,, ,, |
| 72·82 | The stronger edge of the same | 22595 | 4426 | |
| 74·35 | The stronger edge of a band, overlapped by the foregoing | 22741 | 4397 | 4400. A line in spark spectrum, Hartley and Adeney. |
| 75·37 | ,, ,, ,, ,, ,, ,, ,, | 22837 | 4379 | 4378. The same. |
| 77·9 | ,, ,, ,, dark band | 23070·5 | 4335 | |
| 79·5 | ,, ,, ,, band, fainter than foregoing | 23212 | 4325 | 4324·6. The same. |
| 82·32 | ,, ,, ,, ,, stronger ,, | 23747·5 | 4211 | |
| 85·96 | ,, ,, ,, ,, ,, ,, | 23809·5 | 4201 | 4200. A band, Salet. |
| 87·28 | Markings in a band | 23930 | 4179 | A line in spark spectrum. 4180·7, Hartley and Adeney. |
| 88·25 | This band is overlapped by the foregoing | 24019·5 | 4163 | 4170 3. A line in spark spectrum, Hartley and Adeney. |
| 88·98 | The stronger edge of the same | 24087·5 | 4151·5 | |
| 90·32 | The stronger edge of a band overlapped by the foregoing | 24209·7 | 4130·5 | |

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TELLURIUM—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 91·01 | The fainter edge of a band | 24272 | 4120 | 4119·7. A line in spark spectrum, HARTLEY and ADENEY. |
| 92·0 | Markings in the same | 24347 | 4107 | |
| 92·62 | Markings in the same | 24400·5 | 4098 | |
| 93·505 | Markings in the same | 24478 | 4085 | |
| 94·395 | Darker edge of the same | 24555·6 | 4072·5 | 4072·7. A line in spark spectrum, HARTLEY and ADENEY. |
| 97·67 | The fainter edge of a band | 24842·5 | 4025·6 | |
| 99·52 | The stronger edge of the same | 25004·5 | 3999 | |
| 104·05 | The darker edge of a band fainter than the foregoing | 25398·5 | 3937 | |
| 108·51 | ,, ,, ,, ,, ,, ,, | 25775 | 3880 | |
| 117·54 | ,, ,, ,, ,, ,, ,, | 26533·5 | 3769 | |
| 122·68 | ,, ,, ,, ,, ,, ,, | 26964·5 | 3708·5 | |
| 127·05 | ,, ,, ,, ,, ,, ,, | 23717·6 | 3661 | |
| 132·29 | ,, ,, ,, ,, ,, ,, | 27744 | 3604 | |
| 136·70 | ,, ,, very faint band | 28091·5 | 3560 | |
| 155·95 | A strong sharp line | 29555 | 3383·5 | 3382·4. A line in spark spectrum, HARTLEY and ADENEY. |
| 168·41 | A pair of lines | 30478·5 | 3281 | 3280. The same. |
| 169·375 | A pair of lines | 30550 | 3273 | 3273·4. The same. |
| 172·635 | A strong sharp line, succeeded by the water vapour lines | 30790·7 | 3248 | 3246·8. The same. |

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## Antimony.

A very good specimen of metallic antimony was used. Lead and copper were detected in it; the lines belonging to these elements being easily identified. Exposure, 30 minutes.

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 30·155 | The stronger edge of an indistinct band | 18144 | 5511 | |
| 60·6 | The fainter edge of band | 21390 | 4675·5 | |
| 68·96 | The stronger edge of the same | 22209·5 | 4503 | |
| 74·4 | A faint line, or edge of a band | 22746 | 4399·6 | |
| 81·57 | ,, ,, ,, | 23404 | 4273 | |
| 90·23 | ,, ,, ,, | 24202·5 | 4132 | |
| 93·9 | The edge of a faint band | 24518 | 4079 | |
| 95·85 | ,, ,, ,, | 24683 | 4051 | |
| 96·74 | A line or edge of an exceedingly faint band | 24761·5 | 4038·5 | |
| 100·108 | ,, ,, ,, | 25063 | 3990 | |
| 103·21 | The edge of a band | 25311 | 3949·8 | |
| 104·19 | ,, ,, ,, | 25410 | 3935·5 | |
| 105·95 | ,, ,, ,, | 25557 | 3913 | |
| 106·19 | ,, ,, ,, | 25578 | 3910 | |
| 107·71 | ,, ,, ,, | 25707 | 3890 | |
| 110·62 | ,, ,, ,, | 25954 | 3853 | |
| 113·87 | ,, ,, ,, | 26222 | 3813·5 | |
| 116·78 | An indistinct line, or the edge of a band | 26469·5 | 3778 | |
| 118·94 | The edge of a band | 26653 | 3751·9 | |
| 120·26 | | 26764 | 3748·5 | |
| 123·47 | | 27027 | 3700 | |
| 124·69 | A pair of very faint though distinct lines | 27125·5 | 3686·5 | |
| 125·65 | | 27203·5 | 3676 | |
| 127·0 | The edge of an ill-defined band (faint) | 27314 | 3661 | |
| 128·65 | ,, ,, ,, ,, | 27442 | 3664 | |
| 130·26 | A faint line or indistinct edge of a faint band | 27579 | 3626 | |
| 132·49 | ,, ,, ,, ,, | 27760 | 3602 | |
| 135·37 | ,, ,, ,, ,, | 27989 | 3573 | |

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## Bismuth.

A beautifully crystallized specimen of the metal was used. Exposure 30 minutes. It was found to give lines belonging to lead, thallium, copper, and silver. These were easily identified.

| Micrometer measurements in hundredths of an inch. | Description of spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| | A series of overlapping bands. | | | The bands of this spectrum were not so sharply defined as those of lead and tin, and could not be so accurately measured. When two or more readings were not alike, the mean was taken. |
| 22·3 | The weaker or less refrangible edge of the 1st band | 17225 | 5805·5 | |
| 24·65 | A line or narrow band lying upon the 1st band | 17500 | 5714·2 | |
| 26·03 | The more refrangible or stronger edge of 1st band | 19172·2 | 5215·7 | |
| 29·06 | The stronger or more refrangible edge of the 2nd band | 18010·7 | 5549 | |
| 32·85 | The same of 3rd band | 18443 | 5422 | This band is very faint, as also are the succeeding ones, their degraded edges appearing as markings on a continuous spectrum which gradually fades away. |
| 35·63 | ,, ,, 4th ,, | 18750 | 5333 | |
| 36·4 | ,, ,, 5th ,, | 18832 | 5310·1 | |
| 37·0 | ,, ,, 6th ,, | 18895·5 | 5292 | |
| | The bands at this point are feeble and not distinct. | | | |
| 53·3 | Second series of band degraded towards the red | 20615 | 4850·5 | |
| | Feeble indication of 1st band. | | | |
| 58·7 | Very feeble indication of a band | 21165 | 4724·5 | |
| 59·02 | Centre of a broad line or more refrangible edge of a band | 21211 | 4714·5 | This is very strong and broad, extending from 58·92 to 59·1. |
| 59·5 | A line upon a band | 21247 | 4707 | |
| 60·03 | The stronger or more refrangible edge of the 2nd band | 21315·5 | 4691 | |
| 61·0 | The same of 3rd band | 21400 | 4672·8 | |
| 62·75 | ,, ,, 4th ,, | 21590·5 | 4632 | |
| 65·11 | ,, ,, 5th ,, | 21826 | 4582 | |
| 66·93 | ,, ,, 6th ,, | 22007·5 | 4544 | |
| 68·27 | ,, ,, 7th ,, | 22141 | 4516·5 | |
| 69·87 | ,, ,, 8th ,, | 22301 | 4484 | |
| 72·0 | ,, ,, 9th ,, | 22514 | 4441·5 | |
| 73·12 | ,, ,, 10th ,, | 22625 | 4420 | |
| 74·25 | ,, ,, 11th ,, | 22733 | 4399 | |
| | A very weak band extends from 74·9 to 75·16. The more refrangible edge is the stronger. | | | |

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## Bismuth—(continued).

| Micrometer measurements in hundredths of an inch. | Description of spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 75·16 | . . . . . | 22817 | 4382·5 | |
| 76 to 77·0 | There are feebly visible flutings from 76 to 77 . . . . . | 22865<br>22970 | 4373·5<br>4353·5 | |
| 76·09 | The stronger or more refrangible edge of a band . . . . . | 22904·5 | 4366 | |
| 92·8 | There is a continuous spectrum as far as 92·8. | | | |
| 96·2 | A line or marking on a band . . . . . | 23140 | 4321·2 | |
| | This band continues to 105·4. | | | |
| 105·24 | The more refrangible edge of a feeble indistinct band . . . . . | 23498 | 4255·5 | |
| 109·02 | The same . . . . . | 25823·5 | 3872·5 | |
| 111·28 | „ „ . . . . . | 26008 | 3845 | |
| 118·98 | „ „ . . . . . | 26653 | 3752 | |
| 127·35 | „ „ . . . . . | 27342·5 | 3652 | |
| 140·0<br>141·0<br>141·9 | Three feeble lines . . . . . | 28350<br>28417<br>28475 | 3527·9<br>3517·9<br>3510·5 | |
| 198·7 | A strong line coincident with a water-vapour line . . . . . | 32601 | 3067 | |
| 205·5 | | 33070 | 3023·8 | In Hartley and Adeney's spark spectrum of bismuth. |
| 210·1 | | 33386 | 2992·2 | |
| 210·8 | | 33441 | 2983·1 | The same, 2982·9. |
| 219·8 | | 34031 | 2937·5 | The same. |
| 227·0 | A group of weak lines . . . . . | 34483 | 2900·2 | There is a silver spark line at 2901·6, Hartley and Adeney. |
| 227·8 | | 34511 | 2897·2 | In Hartley and Adeney's spark spectrum of bismuth. |

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## Lead.

Assay lead was used. Exposure 40 minutes. Several lines attributed by Mitscherlich to lead oxide are evidently related to the bands described and measured. These are indicated by M.

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 25·63 | More refrangible edge of 1st band degraded towards the less refrangible rays | 17621 | 5675 | |
| 27·065 | More refrangible edge of 2nd band not degraded | 17791 | 5620·5 | 5615, PbO, M. |
| 28·045 | Less " " 3rd band, broad | 17903·5 | 5585 | |
| 31·7 | More " " same not degraded, or very feebly towards the less refrangible rays | 18315 | 5460 | 5460, PbO, M. |
| 33·51 | More refrangible edge of a feeble band, 4th band | 18517·5 | 5400 | |
| 35·4 | " " " band which overlaps the foregoing band, 5th band | 18726·5 | 5340 | 5328, PbO, M. |
| 38·77 | Less refrangible edge of 6th band not well defined | 19079 | 5241 | |
| 39·86 | More " " the same | 19193 | 5210 | 5220, PbO, M. |
| 40·04 | Less " " 7th band | 19252 | 5194 | |
| 42·26 | More " " same | 19456·5 | 5140 | 5144, PbO, M. |
| 45·43 | Marking of feeble band, 8th band | 19797 | 5051 | |
| 48·11 | Less refrangible edge of a band not well defined, 9th band | 20078 | 4980·5 | 4993, PbO, M. |
| 48·86 | Marking on a feeble band, 10th band | 20157 | 4961 | |
| 49·08 | " " " 11th " | 20180 | 4955 | |
| 50·26 | " " " 12th " | 20302 | 4925·5 | |
| 50·7 | " " " 13th " | 20348 | 4914·5 | 4913, PbO, M. |
| 51·23 | " " " 14th " | 20402·5 | 4901·5 | |
| 51·43 | " " " 15th " | 20424 | 4896 | 4880, PbO, M. |
| 53·23 | More refrangible edge of a well-defined band, 16th band | 20585 | 4858 | 4852, M. |
| 54·375 | " " " " " degraded towards the less refrangible rays, 17th band | 20728·5 | 4824 | 4825, M. |
| 57·56 | Well defined, more refrangible edge of a band degraded towards the less refrangible rays, 18th band | 21060·5 | 4748 | |
| 59·34 | More refrangible edge of a band, in continuous spectrum, 19th band | 21243·5 | 4707 | |
| 61·59 | " " " " " " 20th " | 21474 | 4657 | 4664, PbO, M. |
| 63·85 | More refrangible edge or marking of band, in continuous spectrum, 21st band | 21702·5 | 4608 | |

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LEAD—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 64·35 | More refrangible edge or marking of band, in continuous spectrum, 22nd band | 21751 | 4597·5 | 4593, PbO, M. |
| 68·65 | More refrangible edge or marking of band, in continuous spectrum, 23rd band | 22179 | 4508·5 | |
| 71·32 | A line . . . . . | 22446 | 4455 | 4468, PbO, M. |
| 75·84 | A line or band marking (scarcely visible), in continuous spectrum, 24th band | 22881 | 4370·5 | 4381, M. |
| 79·13 | More refrangible edge of a band, in continuous spectrum, degraded towards the less refrangible rays, 25th band | 23177 | 4314·5 | |
| 84·39 | More refrangible edge of a band, in continuous spectrum, degraded towards the less refrangible rays, 26th band | 23666 | 4225·5 | |
| 88·28 | More refrangible edge of a band, in continuous spectrum, degraded towards the less refrangible rays, 27th band | 24022 | 4163 | |
| 89·69 | Apparently the more refrangible edge of a band, in continuous spectrum, degraded towards the less refrangible rays, 28th band | 24152·5 | 4140·5 | |
| 95·35 | A line very strong, broad . . . . . | 24638·5 | 4059 | { 4062·5 } arc, LIVEING and |
| 97·48 | More refrangible edge of a band, in continuous spectrum, degraded towards the less refrangible rays, 29th band | 24826 | 4028 | { 4058·5 } DEWAR. |
| 100·33 | More refrangible edge of a band, degraded towards the less refrangible rays, 30th band | 25077 | 3985 | |
| 102·79 | More refrangible edge of a band, degraded towards the less refrangible rays, 31st band | 25290 | 3954 | |
| 105·92 | More refrangible edge of a band, degraded towards the less refrangible rays, 32nd band | 25854·5 | 3913 | |
| 108·48 | More refrangible edge of a band, degraded towards the less refrangible rays, 33rd band | 25773 | 3880 | |
| 111·79 | More refrangible edge of a band, degraded towards the less refrangible rays, 34th band | 26050 | 3839 | |
| 114·52 | More refrangible edge of a band, degraded towards the less refrangible rays, 35th band | 26282 | 3805 | |
| 116·42 | More refrangible edge of a band, degraded towards the less refrangible rays, but weaker, 36th band | 26438 | 3783 | |
| 119·91 | A line on the more refrangible edge of a band, degraded towards the less refrangible rays, 37th band | 26734 | 3740·5 | |
| 122·05 | Feeble edge of a band, 38th band . . . . . | 26914 | 3715·5 | |

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LEAD—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 124·95 | Very strong, broad, and well-defined line . . . . . | 27146 | 3684 | |
| 126·07 | Very feeble edge of a band, 39th band . . . . . | 27237 | 3671·5 | |
| 127·53 | ,, ,, ,, 40th ,, . . . . . | 27357 | 3655 | |
| 129·0 | Very strong, broad, and well-defined line . . . . . | 27477 | 3639·5 | |
| 131·73 | Feeble edge of a band, degraded towards the less refrangible rays, 41st band | 27699 | 3610 | |
| 133 31 | Feeble, more refrangible edge of band, degraded towards the less refrangible rays, 42nd band | 27825 | 3594 | |
| 134·45 | Feeble, more refrangible edge of band, degraded towards the less refrangible rays, 43rd band | 27836·5 | 3592·5 | |
| 135·53 | Feeble, more refrangible edge of band, barely degraded towards the less refrangible rays, 44th band | 28001·5 | 3571 | |
| 137·17 | Feeble, more refrangible edge of band, barely degraded towards the less refrangible rays, 45th band | 28127 | 3555 | |
| 142·85 | Very feeble edge of band, not clearly defined, 46th band . . . . . | 28560 | 3501·5 | |
| 144·48 | Well-defined edge of a band, degraded towards the less refrangible rays, 47th band | 28685 | 3486 | |
| 148·76 | Feeble edge of a band, 48th band . . . . . | 29012 | 3447 | |
| 150·45 | ,, ,, ,, 49th ,, . . . . . | 29141 | 3431·5 | |
| 153·45 | Well-defined edge of a band, degraded towards the less refrangible rays, 50th band | 29367 | 3405 | |
| 157·82 | Very feeble marking in band, 51st band . . . . . | 29694 | 3368 | |
| 159 62 | Still more feeble marking in band, 52nd band . . . . . | 29828 | 3352·5 | |
| 160·59 | Very feeble edge of band, not clearly defined, 53rd band . . . . . | 29898 | 3345 | |
| 163·57 | ,, ,, ,, degraded towards the less refrangible rays, 54th band | 30120 | 3320 | |
| 165·12 | Very feeble edge of 55th band . . . . . | 30235 | 3307 | |
| 165·59 | Imperfectly defined edge of a double band, 56th band . . . . . | 30269·5 | 3304 | |
| 170·5 | Feeble, more refrangible edge, well defined, of a band, degraded towards the less refrangible rays, 57th band | 30635 | 3264 | |
| 177·77 | Well-defined edge of broad band, also commencement of water vapour lines, 58th band | 31157 | 3209·5 | |
| 239·29 | Very well defined, weak, but sharp line . . . . . | (35294 | 2832·2) | |

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## Tin.

The spectrum of the metal; a very fine series of 47 narrow bands extends from near the sodium line to wave-length 3033·1. Exposure 30 minutes. These bands are degraded towards the rays of least refrangibility.

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 61·07 | The stronger edge of a band first | 21422 | 4668 | |
| 61·63 | ,, ,, ,, | 21478 | 4656 | |
| 63·79 | Feeble edge of a band not well defined | 21695·5 | 4609 | 4605 to 4595 $SnO_2$, Salet. |
| 66·31 | ,, ,, ,, ,, | 21945 | 4557 | |
| 67·54 | ,, ,, ,, ,, | 22068 | 4532 | |
| 68·8 | ,, ,, ,, ,, | 22195 | 4505·5 | |
| 71·37 | The more refrangible edge of a band well defined, degraded towards the rays of least refrangibility | 22449 | 4456 | |
| 71·7 | The more refrangible edge of a band well defined, degraded towards the rays of least refrangibility | 22450·5 | 4454 | |
| 75·92 | Feeble edge of a well-defined band | 22888 | 4369 | |
| 77·16 | ,, ,, ,, ,, | 23003·8 | 4347 | |
| 79·68 | More refrangible edge of a band, degraded towards the rays of least refrangibility | 23228 | 4305 | |
| 82·0 | More refrangible edge of a band, but apparently not degraded | 23445 | 4265 | |
| 83·33 | ,, ,, ,, degraded towards the rays of least refrangibility | 23569·5 | 4243 | 4244 to 4236 $SnO_2$, Salet. |
| 84·63 | More refrangible edge of a band, degraded towards the rays of least refrangibility | 23688 | 4221·5 | |
| 90·51 | More refrangible edge of a band not clearly defined, degraded towards the rays of least refrangibility | 24227 | 4128 | |
| 91·21 | More refrangible edge of a band, degraded towards the rays of least refrangibility | 24278 | 4119 | |
| 93·25 | More refrangible edge of a band, degraded towards the rays of least refrangibility | 24455·5 | 4089 | 4083 to 4077 $SnO_2$, Salet. |
| 97·11 | More refrangible edge of a band, degraded towards the rays of least refrangibility | 24793·5 | 4033 | |
| 100·085 | More refrangible edge of a band, degraded towards the rays of least refrangibility | 25120 | 3981 | |
| 102·75 | More refrangible edge of a band, degraded towards the rays of least refrangibility | 25285 | 3955 | |
| 106·4 | More refrangible edge of a band, degraded towards the rays of least refrangibility | 25595 | 3907 | |
| 109·2 | More refrangible edge of a band, degraded towards the rays of least refrangibility | 25835 | 3871 | |

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TIN—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | λ. | Remarks. |
|---|---|---|---|---|
| 111·6 | More refrangible edge of a band, degraded towards the rays of least refrangibility | 26055 | 3841 | |
| 112·78 | More refrangible edge of a band, and not clearly defined band | 26132 | 3827 | |
| 114·14 | ,, ,, ,, ,, | 26244 | 3810 | |
| 116·05 | Feeble, ill-defined, edge of a band | 26423 | 3787 | |
| 118·18 | ,, ,, ,, ,, | 26588 | 3761 | |
| 121·04 | Very strong, and well defined, more refrangible edge of a band, degraded towards the rays of least refrangibility | 26830 | 3727 | |
| 123·8 | Very strong, and well defined, more refrangible edge of a band, degraded towards the rays of least refrangibility | 27054 | 3696 | |
| 131·0 | The feeble edge of a band | 27640 | 3618 | |
| 133·71 | More refrangible edge of a strong band, degraded towards the rays of least refrangibility | 27857 | 3590 | |
| 138·02 | Feeble, ill-defined, more refrangible edge of, or marking in, a band | 28190 | 3547 | |
| 144·07 | Well defined, more refrangible edge of a strong band, degraded towards the least refrangible rays | 28653 | 3490 | |
| 148·32 | Ill-defined edge of a feeble band | 28977·5 | 3451 | |
| 151·62 | Well-defined edge of a band, degraded towards the rays of least refrangibility | 29228 | 3421 | |
| 154·725 | Well-defined edge of a band, degraded towards the rays of least refrangibility | 29462·5 | 3394 | |
| 162·43 | More refrangible edge of a very strong band, degraded towards the rays of least refrangibility | 30036·5 | 3329·5 | |
| 166·22 | Ill-defined edge of, or marking in, a feeble band. | 30316 | 3298·5 | |
| 170·08 | More refrangible edge of a well-defined, strong band, degraded towards the rays of least refrangibility | 30602 | 3268 | |
| 174·34 | Well-defined, more refrangible edge of a band, degraded towards the rays of least refrangibility. | 30915 | 3234·5 | |
| 178·25 | Well-defined, more refrangible edge of a stronger band than the foregoing, degraded towards the rays of least refrangibility | 31190·5 | 3206 | |
| 182·0 | Well-defined, more refrangible edge of a stronger but narrower band than the foregoing, degraded towards the rays of least refrangibility | 31461 | 3179 | |
| 194·41 | The well-defined edge of a band among the water-vapour lines | 32310 | 3095 | |
| 198·29 | ,, ,, ,, ,, ,, ,, | 32582 | 3068·6 | |
| 203·07 | Very feeble band marking | 32907 | 3038·8 | |
| 207·11 | ,, ,, ,, | 33186·5 | 3031 | |
| 211·735 | ,, ,, ,, | 33454 | 2989 | |

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## Silver.

### Exposure 30 minutes.

| Micrometer measurements in hundredths of an inch. | Description of spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 28·85 | Faint indication of a line or marking . . . . . | 17796·5 | 5556·7 | 5556·6, Thalén. |
| 30·05 | ,, ,, ,, . . . . . | 18132·5 | 5515·0 | |
| 30·98 | ,, ,, ,, . . . . . | 18236 | 5483·7 | 5486·6, Thalén. |
| 31·51 | ,, ,, ,, . . . . . | 18303·6 | 5463·4 | 5464·1, Thalén. |
| 59·82 | Less refrangible edge of 1st band . . . . . | 21294 | 4696·0 | |
| 61·875 | More ,, ,, | 21502·3 | 4650·8 | There is a pair of lines in the green which do not appear on the photographs. |
| 63·465 | Less refrangible edge of 2nd band . . . . . | 21663 | 4616·5 | |
| 64·665 | More ,, ,, | 21781·6 | 4591·0 | |
| 65·99 | Less refrangible edge of 3rd band . . . . . | 21913·4 | 4563·4 | |
| 67·42 | More ,, ,, | 22056·8 | 4533·4 | |
| 68·15 | Less refrangible edge of 4th band . . . . . | 22129·2 | 4519·0 | 4518, L. de B., in $AgNO_3$ sol. |
| 69·54 | More ,, ,, | 22268·2 | 4490·9 | |
| 70·54 | Less refrangible edge of 5th band . . . . . | 22367·5 | 4470·9 | 4475·1, Thalén, also L. de B. |
| 71·59 | More ,, ,, | 22473 | 4449·8 | |
| 72·87 | Less refrangible edge of 6th band . . . . . | 22600 | 4424·8 | |
| 73·73 | More ,, ,, | 22683·3 | 4408·6 | |
| 74·41 | Less refrangible edge of 7th band . . . . . | 22747 | 4396·2 | 4396, L. de B., in $AgNO_3$ sol. |
| 75·78 | More ,, ,, | 22865 | 4373·5 | |
| 76·39 | Less refrangible edge of 8th band . . . . . | 22932 | 4360·7 | |
| 77·17 | More ,, ,, | 23004·6 | 4347·0 | |
| 78·12 | Less refrangible edge of 9th band . . . . . | 23090 | 4330 9 | |
| 79·935 | More ,, ,, | 23252·5 | 4300·5 | |
| 80·28 | Less refrangible edge of 10th band . . . . . | 23284·6 | 4294·7 | |
| 80·955 | More ,, ,, | 23347 | 4283·2 | |
| 81·5 | Less refrangible edge of 11th band . . . . . | 23398 | 4273·9 | |
| 82·435 | More ,, ,, | 23484·8 | 4258·0 | |
| | The 11th band is very indistinct, and is followed by a diffused spectrum extending from about 82·435 to 84·1, with markings measured at— | | | |
| 82·985<br>83·64<br>84·05 | Markings . . . . . | 23536<br>23595<br>23635 | 4244·9<br>4238·2<br>4231·0 | |

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## Silver—(continued).

| Micrometer measurements in hundredths of an inch. | Description of spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 87·435 | Another band commences at 87·435, extending to 86·685, and overlaps another fainter band, which extends to 89·25. | 23944·2 | 4176·4 | |
| 86·685 | | 24059·4 | 4156·4 | |
| 89·25 | | 24112 | 4147·4 | |
| 92·37 | Three faint markings, like fine lines in a portion of continuous spectrum | 24379 | 4102·0 | |
| 93·12 | | 24444·5 | 4091·0 | |
| 93·32 | | 24462 | 4088·0 | |
| 97·38 | A fine sharp line | 24817 | 4030·3 | |
| 115·85 | Marking like an exceedingly faint sharp line | 26347 | 3795·4 | |
| 117·0 | ,, ,, ,, ,, | 26488 | 3775·2 | |
| 122·3 | ,, ,, ,, ,, | 26934 | 3712·7 | |
| 126·0 | ,, ,, ,, ,, | 27232 | 3672·0 | |
| 129·75 | A distinct fine line | 27537·2 | 3631·5 | |
| 135·02 | ,, ,, | 27960 | 3576·5 | |
| 138·82 | ,, ,, | 28253·4 | 3539·5 | 3541·3, H. and A. |
| 141·03 | A pair of faint lines | 28421·5 | 3518·4 | |
| 141·93 | | 28489·4 | 3510·0 | |
| | A strong group of 8 fine silver lines. These increase in strength with increase in refrangibility, and become closer together (commencing at 148·095). | | | |
| 148·095 | 1st line of first group | 28960·5 | 3453·0 | |
| 148·345 | 2nd ,, ,, | 28979·3 | 3450·7 | |
| 148·545 | 3rd ,, ,, | 28995 | 3448·0 | |
| 148·78 | 4th ,, ,, | 29013 | 3446·7 | |
| 148·973 | 5th ,, ,, | 29027 | 3445·1 | |
| 149·405 | 6th ,, ,, | 29060·7 | 3441·1 | |
| 149·905 | 7th ,, ,, | 29098·6 | 3436·5 | |
| 150·37 | 8th ,, ,, | 29135 | 3432·3 | |
| | Another group of 10 fine silver lines, which increase in strength with their refrangibility, and become closer together. | | | |
| 151·09 | 1st line of second group | 29139 | 3431·8 | |
| 151·56 | 2nd ,, ,, | 29224 | 3421·8 | |

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## Silver—(continued).

| Micrometer measurements in hundredths of an inch. | Description of spectrum. | $\frac{1}{\lambda}$. | λ. | Remarks. |
|---|---|---|---|---|
| 151·925 | 3rd line of second group | 29252·5 | 3418·5 | |
| 151·985 | 4th ,, ,, | 29256 | 3418·1 | |
| 152·34 | 5th ,, ,, | 29282 | 3415·1 | |
| 152·85 | 6th ,, ,, | 29321 | 3410·5 | |
| 153·25 | 7th ,, ,, | 29351·8 | 3407·0 | |
| 153·675 | 8th ,, ,, | 29383·7 | 3403·2 | |
| 153·985 | 9th ,, ,, | 29403·2 | 3401·0 | |
| 154·305 | 10th ,, ,, | 29431·4 | 3397·8 | |
| | A third group consisting of 19 fine silver lines commences at 154·625. These increase in strength as they extend farther into the region of the less refrangible rays. | | | |
| 154·625 | 1st line of third group | 29455 | 3395·0 | |
| 154·915 | 2nd ,, ,, | 29477 | 3392·5 | |
| 155.275 | 3rd ,, ,, | 29504 | 3389·4 | |
| 155·65 | 4th ,, ,, | 29532·3 | 3386·2 | |
| 155·95 | 5th ,, ,, | 29555 | 3383·5 | Very strong line here in arc and spark. |
| 156·17 | 6th ,, ,, | 29571 | 3381·7 | The rays extending from this line, which is the maximum of intensity, are not continuous, but consist of an exquisite series of fine lines very close together and growing wider apart as they become less refrangible, down to 153. |
| 156·57 | 7th ,, ,, | 29600·6 | 3378·4 | |
| 157·1 | 8th ,, ,, | 29633·5 | 3374·7 | |
| 157·42 | 9th ,, ,, | 29664 | 3371·1 | |
| 157·985 | 10th ,, ,, | 29706 | 3366·3 | |
| 158·49 | 11th ,, ,, | 29743·5 | 3362·2 | |
| 158·79 | 12th ,, ,, | 29766 | 3359·5 | |
| 158·95 | 13th ,, ,, | 29778 | 3358·2 | |
| 159·02 | 14th ,, ,, | 29783 | 3357·7 | |
| 159.5 | 15th ,, ,, | 29818·2 | 3354·8 | |
| 159·945 | 16th ,, ,, | 29851 | 3350·0 | |
| 160·405 | 17th ,, ,, | 29885·7 | 3347·2 | |
| 160·43 | 18th ,, ,, | 29887·5 | 3347·0 | |
| 160·95 | 19th ,, ,, | 29925·6 | 3341·6 | |
| | These groups of lines really constitute broad bands degraded on the side of least refrangibility. | | | |

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## Silver—(continued).

| Micrometer measurements in hundredths of an inch. | Description of spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| | A fourth group of 6 fine silver lines, which are so faint and indistinct that only approximate measurements could be obtained. | | | |
| 161·59 | 1st line of fourth group . . . . . | 29973·2 | 3336·4 | |
| 161·88 | 2nd „ „ . . . . . | 29995 | 3333·8 | |
| 162·155 | 3rd „ „ . . . . . | 30015 | 3331·7 | |
| 162·32 | 4th „ „ . . . . . | 30027 | 3330·4 | |
| 162·55 | 5th „ „ . . . . . | 30044·5 | 3328·4 | |
| 162·65 | 6th „ „ . . . . . | 30051·5 | 3327·4 | |
| | This group of lines is succeeded by a series of bands extending from 163·58 to 168·27. | | | |
| 163·58 | Strongest edges of the 9 narrow bands constituting this series. These are slightly degraded toward the less refrangible rays. This variation is more marked with those bands which are farthest from the red end of the spectrum. | 30121 | 3319·9 | |
| 164·15 | | 30163 | 3315·3 | |
| 164·895 | | 30218·3 | 3309·2 | |
| 165·36 | | 30252·2 | 3305·5 | |
| 166·39 | | 30328·5 | 3297·3 | |
| 166·73 | | 30353·5 | 3293·5 | |
| 167·39 | | 30402·5 | 3289·2 | |
| 167·85 | | 30437 | 3285·5 | |
| 168·27 | | 30468 | 3282·1 | Very strong line occurs here in (centre), both arc and spark. |
| 168·985 | | 30521 | 3276·4 | |
| | This series terminates in a very (centre) strong band degraded towards the less refrangible end of the spectrum. | | | |
| From 168·42 to 169·53 | | | | |
| 169·65 | A faint line . . . . . | 30569·2 | 3271·3 | |
| 169·9 | A sharp and well-defined line . . . . . | 30588 | 3269·3 | |

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## Iron.

When investigating the spectrum of iron a number of materials were used, namely, pure metallic iron, tool steel, spiegel-eisen, ferro-manganese, silico-spiegel, and ferro chrome. Of the compounds of iron the following were taken: ferric oxide, ferrous sulphide, ferrous phosphate. Exposure from 15 to 35 minutes, generally 30 minutes. Pure iron and its compounds give spectra which are identical. Ferrous phosphate, however, yields a spectrum which contains a band due to phosphorus pentoxide, and a line also which is observed in this phosphorus compound, and in no other substance which, up to the present, I have photographed.

The metal and its compounds emit more or less strongly a series of bands lying between λ 5928 and 5537 which belong to iron. Steel also emits bands due to manganese, and the strong pair of lines of this metal.

The lines occurring in ferric oxide spectra are indicated, the description of the spectrum, and also those which are known to be prominent solar lines.

The spectrum was photographed from Turton's tool steel. R. means normal lines in Rowland's map. K. and R. (Kayser and Runge's) measurements; *r* means that they observed the lines to be reversed in the arc, from which their measurements were made. C., Cornu's measurements. W., Marshall Watts.

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | λ. | Remarks. |
|---|---|---|---|---|
| 19·0 | A faint band extending from 19 to 24, after which it darkens up to 25·3 | 16870 | 5927·7 | 5930·25. Strong line, K. and R. |
| 24·0 | | 17426 | 5738·5 | |
| 25·3 | | 17575 | 5689·8 | 5688 W. Splendid double line in Bessemer iron, Spiegel-eisen and $MnO_2$ spectra. |
| 25·3 | A dark band extending from 25·3 to 27·2, after which it gradually becomes fainter up to 34·1; within this latter portion there are bands or broad lines with their centres at 27·9 and 29·5 | 17575 | 5689·8 | |
| 27·2 | | 17795 | 5619·4 | |
| 27·9 | | 17875 | 5594·3 | |
| 29·5 | | 18060 | 5537·1 | 5544, Brightest edge of band. W. |
| 34·1 | | | | |
| | In ferric oxide there is a band with a maximum of intensity about 25, extending to 28, and decreasing towards and as far as 35. | 18570 | 5385 | Manganese. |

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## Iron—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| | Beyond the bands above-mentioned there is a continuation of diffused rays, or an indistinct band up to 155, in which are to be found the principal iron lines, all of which have been most carefully measured by Liveing and Dewar, and more recently by Kayser and Runge. | | | |
| 36 | | 18780 | 5324·8 | 5324·31 R. |
| 37·92 | | 18988·5 | 5266·5 | 5266·72. |
| 70·2 | | 22325 | 4479·3 | |
| 71·2 | | 22423 | 4459·7 | 4459·24. |
| 73·0 | | 22590 | 4426·7 | 4427·44. |
| 74·2 | | 22698 | 4405·7 | 4404·88. 4404 in Bessemer flame spectra, not identified, W. |
| 75·4 | | 22810 | 4384·0 | 4383·7. |
| 75·8 | | 22848 | 4376·8 | 4376·04 R. |
| 78·7 | | 23115 | 4326·2 | 4325·92 R. |
| 79·8 | Fraunhofer's G | 23210 | 4308·5 | 4307·96 R. |
| 81·4 | Two lines at this point measured as one<br>A double line in appearance, but in reality a triplet | 23406 | 4272·4 | 4271·93<br>4271·3 } K. and R. |
| 81·9 | | 23436 | 4266·9 | 4267·97 R. K. and R. |
| 94·4 | | 24562 | 4071·5 | 4071·79. |
| 95·37 | | 24640·5 | 4058·3 | |
| 95·78 | | 24676·7 | 4052·4 | 4052·75. K. and R. |
| 96·13 | | 24707 | 4047·5 | 4048·82 or 4045·9 R. K. and R. |
| 97·22 | | 24803 | 4031·7 | 4030·84. K. and R. |
| 98·06 | Strong double line highly characteristic of manganese | 24876·5 | 4019·8 | Manganese. |
| 99·26 | | 24982 | 4002·9 | 4005·9 ? |
| 99·69 | | 25020 | 3996·8 | 3997·49<br>3998·16 |
| 100·83 | | 25122 | 3980·6 | |
| 104·85 | Observed in the ferric oxide spectrum | 25465·5 | 3926·6 | 3928·05. K. and R. |
| 105·3 | ,, ,, ,, ,, ,, | 25503 | 3921·1 | 3923. K. and R. |
| 105·72 | | 25538 | 3915·7 | 3920·36<br>3916·82 R. } K. and R. |
| 106·6 | | 25613 | 3904·2 | 3904·00 R.<br>3903·46 R. } K. and R. |

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IRON—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 106·9 | In $Fe_2O_3$ spectrum. There is a group of lines here which extends from λ3926·6 to 3749·4 | 25638·5 | 3900·4 | 3899·8. K. and R. |
| 107·09 | . . . . . | 25655 | 3897·8 | 3898·05. K. and R. |
| 107·2 | In $Fe_2O_3$ . . . . . | 25664 | 3896·5 | 3895·75. K. and R. |
| 107·34 | . . . . . | 25676 | 3894·6 | 3894·09. K. and R. |
| 107·59 | . . . . . | 25697·5 | 3891·5 | 3892·02. 3890·96. K. and R. |
| 107·9 | In $Fe_2O_3$ . . . . . | 25718 | 3888·2 | 3888·63. K. and R. |
| 108·08 | . . . . . | 25739 | 3885·1 | 3886·38. 3885·61. K. and R. |
| 108·47 | . . . . . | 25772 | 3880·2 | |
| 108·68 | In $Fe_2O_3$ . . . . . | 25789·7 | 3877·6 | 3878·82. K. and R. |
| 108·93 | . . . . . | 25811 | 3874·3 | 3873·88 or 3872·61. K. and R. |
| 110·0 | In $Fe_2O_3$ . . . . . | 25903 | 3860·5 | 3860·03. K. and R. |
| 110·13 | In $Fe_2O_3$ . . . . . | 25914 | 3858·9 | 3858·49. K. and R. |
| 110·55 | | 25948 | 3853·7 | 3854·51. K. and R. 3853·7 C. |
| 111·21 | | 26005 | 3845·4 | 3846·96. K. and R. 3845·9 C. |
| 111·53 | A group of closely adjacent lines . . . . . | 26032 | 3841·4 | 3841·9. K. and R. |
| 111·7 | | 26047 | 3839·1 | 3840·58. K. and R. |
| 112·15 | | 26074 | 3835·2 | 3836·48 3834·37. K. and R. |
| 112·85 | In $Fe_2O_3$ spectrum . . . . . | 26137 | 3825·9 | 3827·96. K. and R. 3826·04. K. and R. |
| 113·1 | | 26166 | 3821·5 | 3821·32. K. and R. |
| 113·15 | In $Fe_2O_3$ . . . . . | 26170 | 3821·2 | 3821·32. K. and R. |
| 113·25 | „ CORNU'S **L** solar line . . . . . | 26179·5 | 3819·7 | 3820·56. K. and R. **L**. |
| 113·99 | | 26242·5 | 3810·6 | 3810·89. K. and R. |
| 114·18 | | 26259 | 3808·1 | 3808·8. K. and R. |
| 115·29 | . . . . . | 26342·5 | 3796·1 | 3975·13. K. and R. |
| 116·18 | . . . . . | 26418·3 | 3785·2 | 3786·07. K. and R. |
| 117·195 | . . . . . | 26504·8 | 3772·6 | 3773·84. K. and R. |
| 117·7 | . . . . . | 26555 | 3765·3 | 3767·3. K. and R. |
| 117·9 | . . . . . | 26572 | 3763·3 | 3763·9. K. and R. |
| 118·3 | In $Fe_2O_3$ . . . . . | 26607 | 3757·9 | 3758·36. K. and R. |
| 118·93 | . . . . . | 26652·5 | 3751·9 | 3751·97. K. and R. |

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IRON—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | λ. | Remarks. |
|---|---|---|---|---|
| 119·1 | In $Fe_2O_3$ | 26675 | 3749·4 | 3749·61. K. and R. |
| 119·25 | A double line | 26679 | 3748·1 | 3748·39. K. and R. |
| 119·3 | | 26683 | 3747·6 | 3747·09 R. K. and R. |
| 119·65 | A prominent group of lines extending to λ3705·5 | 26712·5 | 3743·5 | 3745·67. K. and R.<br>3743·45. K. and R. |
| 120·1 | In $Fe_2O_3$ | 26755 | 3736·9 | 3737·27. K. and R. |
| 120·25 | ,, | 26770 | 3735·5 | 3735. K. and R. |
| 120·96 | A double line. CORNU'S **M** solar line | 26823 | 3728·2 | 3727·78. K. and R. **M**. |
| 121·0 | | 26825 | 3727·9 | 3727·13. K. and R. |
| 121·5 | | 26865 | 3722·3 | |
| 121·7 | In $Fe_2O_3$ | 26880 | 3720·2 | 3720·07. K. and R. |
| 122·9 | ,, | 26977 | 3705·5 | 3705·7. K. and R. |
| 124·4 | | 27103 | 3688·5 | 3687·77. K. and R. |
| 124·9 | | 27142 | 3685·8 | 3687·58. K. and R., or 3686·10. |
| 125·15 | In $Fe_2O_3$ | 27162 | 3681·6 | 3680·43. K. and R. |
| 128·2 | ,, | 27407 | 3648·6 | 3647·99. K. and R. |
| 130·0 | ,, | 27550 | 3631·0 | 3631·62. K. and R. |
| 131·9 | | 27700 | 3609·2 | 3608·99. K. and R. |
| 134·7 | In $Fe_2O_3$. CORNU'S **N** solar line | 27917 | 3581·1 | 3581·32. K. and R. **N**. |
| 135·8 | ,, | 28005 | 3569·6 | 3570·23. K. and R. |
| 136·1 | | 28028 | 3565·0 | 3565·5. K. and R. |
| 140·0 | | 28328 | 3531·2 | |
| 143·1 | | 28567 | 3501·8 | 3500·64. K. and R. |
| 143·9 | In $Fe_2O_3$ | 28630 | 3492·3 | 3490·65. K. and R. |
| 145·6 | ,, | 28760 | 3475·5 | 3476·75. K. and R.<br>3475·52. K. and R. |
| 146·5 | ,, | 28835 | 3460·9 | 3460·02. K. and R. or 61·5 C. |
| 149·1 | CORNU'S **O** solar line | 29053 | 3440·8 | 3441·07. K. and R. **O**. |
| 149·4 | In $Fe_2O_3$ | 29068 | 3440·2 | 3440·69. K. and R. |
| 199·9 | | 32689 | 3059·1 | 3059·19. K. and R. |
| 201·8 | CORNU'S **S** solar line. | 32815 | 3047·4 | 3047·71. K. and R. **S**. |
| 203·1 | | 32905 | 3039·1 | 3040·54. K. and R. |
| 205·9 | In $Fe_2O_3$. CORNU'S **T** solar line | 33100 | 3021·1 | 3021·15. K. and R. **T**.<br>3020·7. K. and R. |

## Nickel.

The metal and oxide were both examined, and the lines photographed were compared with those obtained by Cornu in the arc, and by Liveing and Dewar in the arc, the spark, in explosions of oxygen and hydrogen within tubes containing nickel, and also in the flame of nickel tetra-carbonyl.

Cornu "Spectre Normal du Soleil." 'Annales de l'École Normale,' 2 ser., vol. 9. 1880.

Liveing and Dewar, 'Phil. Trans.,' vol. 179, pp. 231–256, and 'Roy. Soc. Proc.,' vol. 52, p. 117.

The lines were measured by the ivory scale and were all identified with the exception of two, about which there is a slight doubt, namely 3574 and 3496.

The metal used was rolled nickel, which owes its malleability to a little manganese. The indications of the presence of this element were very evident from the bands between 5700 and 5300, and the double line 4031·8 and 4029·9.

The metal was exposed for half-an-hour, and the oxide, which yielded the better spectrum, one hour.

| Ivory scale numbers. | $\frac{1}{\lambda}$. | $\lambda$. | Liveing and Dewar's measurements. $\lambda$. | Remarks. |
|---|---|---|---|---|
| 110·1 | 25900 | 3859 | 3857·8 | Common to $Ni(CO)_4$, arc and spark spectra. Not seen in explosions. |
| 114·2 | 26255 | 3809 | 3806·6 | Unless exceptions are stated, all lines are common to the five different spectra (arc, spark, nickel carbonyl flame, and oxy-hydrogen explosions) as observed by Liveing and Dewar. |
| 116·2 | 26426 | 3784 | 3783·0 | |
| 116·9 | 26485 | 3776 | 3775·0 | |
| 131·0 | 27628 | 3619 | 3618·8 | |
| 131·85 | 27695 | 3611 | 3609·8 or 3612·1 | |
| 133·0 | 27785 | 3599 | 3597·0 | Not in $Ni(CO)_4$ flame. |
| 135·5 | 27980 | 3574 | .. | 3572·9, Cornu. |
| 136·0 | 28020 | 3569 | 3571·2 | 3570·8, Cornu. |
| 140·25 | 28347 | 3527 | 3527·1 | Not in explosions. |
| 141·25 | 28425 | 3518 | 3519·1 | " " |
| 141·8 | 28467 | 3513 | 3514·4 | |
| 142·8 | 28547 | 3503 | 3501·8 | Not in $Ni(CO)_4$ nor explosions. |
| 143·6 | 28607 | 3496 | 3492·3 | |
| 144·5 | 28675 | 3487 | 3485·2 | " " " " |
| 145·8 | 28777 | 3475 | 3470·8 | " " " " |
| 147·0 | 28878 | 3462 | 3461·1 | |
| 147·25 | 28900 | 3460 | 3457·9 | 3457·8 in $Ni(CO)_4$. Not in explosions. |
| 148·0 | 28962 | 3453 | 3452·9 | Not in $Ni(CO)_4$ spectrum. A line at 3452·3 occurs in $Ni(CO)_4$ spectrum, arc, and spark, but not in explosion spectrum. |
| 148·75 | 29025 | 3445 | 3445·7 | |
| 149·75 | 29105 | 3436 | 3436·7 | Not in explosions. |
| 150·1 | 29131 | 3433 | 3433·0 | |
| 151·2 | 29213 | 3423 | 3423·1 | |
| 152·2 | 29284 | 3415 | 3413·8 | |
| 154·8 | 29477 | 3392 | 3392·4 | |
| 155·0 | 29492 | 3391 | 3390·4 | |
| 156·1 | 29573 | 3381 | 3380·0 | |
| 157·4 | 29673 | 3370 | 3371·3 | 3371·3 in $Ni(CO)_4$. Not in explosions. 3370 is probably the line 3368·9 |
| | | | 3368·9 | |
| | | | 3367·2 | |
| 163·9 | 30157 | 3316 | 3315·1 | Not in explosions. |
| 174·5 | 30934 | 3233 | 3232·6 | |

## Cobalt.

The metal and oxide were both examined. The lines photographed were compared with those measured by Liveing and Dewar in the arc and spark. ('Phil. Trans.,' vol. 179, p. 231.)

Measurements were made with the ivory scale, and all the lines were identified.

The oxide and metal, as in the case of nickel, give the same spectrum. The exposure of the oxide was double that given to the metal. As in the preparation of malleable cobalt, some maganese is added; the bands and lines of this element appear in the photograph, but less distinctly than in the metallic nickel.

| Scale numbers | $\frac{1}{\lambda}$. | $\lambda$. | Liveing and Dewar's measurements. $\lambda$. | Remarks. |
|---|---|---|---|---|
| 91·2 | 24277 | 4119 | .. | 4120 Huggins. |
| 99·8 | 25026 | 3996 | 3997·3 | On comparing the two series of wave-lengths it will be seen that the difference between them is rather larger than usual, which appears to be due to the scale not being quite accurately adjusted between certain points which are clearly indicated. |
| 107·3 | 25640 | 3899 | 3905·2 | |
| 109·0 | 25804 | 3875 | 3873·2 | |
| 111·15 | 25990 | 3847·5 | 3844·8 | |
| 131·0 | 27628 | 3819·5 | .. | |
| 131·85 | 27688 | 3612 | 3611·3 | |
| 132·6 | 27755 | 3603 | 3601·6 | |
| 133·25 | 27805 | 3596 | 3594·4 | |
| 135·1 | 27950 | 3578 | 3577·4 (more probably 3574·9) | The wave-lengths do not approximate so closely to Liveing and Dewar's measurements as is the case with those in the nickel spectrum. |
| 135·75 | 28000 | 3571 | 3568·9 | |
| 139·4 | 28280 | 3536 | 3532·8 | |
| 139·9 | 28320 | 3531 | 3529·3 | |
| 140·1 | 28335 | 3529 | 3528·4 | |
| 140·3 | 28352 | 3527 | .. | |
| 141·4 | 28437 | 3517 | 3517·7 | |
| 141·8 | 28467 | 3513 | 3512·0 | |
| 142·15 | 28495 | 3509·5 | {3509·3, 3509·7} | |
| 142·7 | 28537 | 3504 | 3502 | |
| 143·6 | 28607 | 3496 | 3495·1 | |
| 145·7 | 28710 | 3483 | 3482·7 | |
| 146·5 | 28835 | 3468 | 3465·2 | |
| 147·0 | 28878 | 3463 | 3462·2 | |
| 147·2 | 28895 | 3461 | 3460·6 | |
| 147·9 | 28953 | 3454 | 3452·9 | |
| 148·4 | 28995 | 3449 | {3448·6, 3448·9} | |
| 149·0 | 29045 | 3443 | 3443·0 | |
| 150·2 | 29137 | 3432 | {3432·9, 3432·4} | |
| 152·2 | 29285 | 3415 | 3414·2 | |
| 152·4 | 29300 | 3413 | {3411·7, 3412·0} | |
| 152·9 | 29336 | 3409 | 3408·6 | |
| 153·3 | 29365 | 3405 | 3404·5 | |

## Chromium.

The spectrum obtained from ferro-chrome containing 22 per cent. of chromium, contains six lines due to chromium, and in addition bands and lines of iron. The bands extend from 24 to 28·3, and continue weaker as far as 35. Manganese lines are also very strong.

| Ivory scale numbers. | Description of spectrum. | $\frac{1}{\lambda}$. | λ. | Remarks. |
|---|---|---|---|---|
| | | | | Ångström and Thalén. |
| 80·6 | A group of three well-defined lines | 2331 | 4290 | 4289·4 |
| 81·4 | | 2338 | 4277 | 4274·6 |
| 82·75 | | 2350 | 4255 | 4253·9 |
| | | | | Liveing and Dewar. |
| 132·2 | A group of three well-defined lines | 27724 | 3607 | 3606 |
| 133·3 | | 27810 | 3595 | 3593 |
| 134·9 | | 27935 | 3580 | 3578 |

## Chromic Trioxide.

This substance gives, in addition to the above, two groups of three lines, a continuous spectrum, strong, from close to the sodium line in the yellow, but a little less refrangible up to λ 3820.

## Iridium.

This element occasioned some difficulties. Strips of iridium, twisted into loops, were obtained from Messrs. Johnson and Matthey some years ago for the purpose of serving as supports for the alkalies and alkaline earths in the oxy-hydrogen blowpipe. To this use it was put with some success and found convenient, but with oxides capable of undergoing reduction, even such as cupric oxide, it became corroded. It was found to be a convenient support for silicates which are fusible, but on examining the spectrum of silica, several lines were discovered which were not due to silica.

Three varieties of silica were tested—1st, Silica precipitated from sodium silicate. This yielded lines identified with iron even after treatment with hydrochloric acid. 2nd, Silica precipitated from silicon fluoride by passing the gas into water. The silica was evaporated from the hydrofluosilicic acid by filtration through absolutely pure ashless filter-paper. Even this showed a number of lines which at first were taken to be those of iron. 3rd, Rock crystal exposed to the hottest part of the flame on iridium for one hour gave nothing beyond the sodium lines in the yellow, mean λ 5892, and in the ultra-violet λ 3303.

To prove the origin of the lines which had been previously observed, a piece of

clean iridium was heated in the flame for seventy minutes and the spectrum photographed.

When the wire was at its highest temperature the flame assumed a peculiar bluish colour and the wire became very thin. The spectrum obtained proved to be similar to that previously obtained from pure silica.

A second spectrum was taken on the same plate, a little silica being placed on the loop of iridium. The spectrum was similar to the first, the lines being the same, but weaker, as the silica acted as a glaze and protected the wire.

It is perfectly evident that this metal was to some extent vaporized in the flame, and that the vapour emits a line spectrum.

The following are measurements of the lines photographed :—

| λ. | λ. | λ. | λ. |
|---|---|---|---|
| 4386 | | 3599 | 3479 |
| 4256 | 3812 | 3596 | 3475 |
| 3965 | 3772 | 3533·5 | 3464 |
| 3937 | 3705 | 3511·5 | 3436·4 |
| 3860 | 3696 | 3508·7 | 3400 |
| 3815 | 3663 | 3484·3 | 3328 |

These lines have not yet been identified, but they are suspected to be due to osmium.

A small strip of pure iridium, for which I am indebted to Mr. George Matthey, F.R.S., was exposed to the flame for three hours and a quarter, and a line spectrum with a small portion of a continuous spectrum was photographed. Undoubtedly the iridium was volatilized, for it lost weight to the extent of 0·0826 grm., and the end was worn away by the flame impinging upon it. The spectrum was very weak, the lines were not those referred to above, and it is suspected that some of them at least are due to a gaseous spectrum, or possibly to a series of the lines belonging to the spectrum attributed to water vapour which have not previously been observed.

The fact that iridium is slightly volatile has undoubtedly been proved, but if the metal is pure it may be used advantageously for the purpose of supporting irreducible oxides in the oxy-hydrogen blow-pipe flame.

## Aluminium.

When the metal, in the form of foil, is burnt in the oxy-hydrogen blow-pipe, it gives a spectrum which is continuous, but in which some few lines or narrow bands are visible. There can be little doubt that these are due to impurities, principally iron. With the exception of three the lines are all very faint. The measurements, which are only approximations, owing to the indefinite character of the lines, are the

following:—λ 4047 broad line, Fe; 4033, Fe; 4023, Fe; 4004·5 Fe; 3996, Fe; 3975, CaO; 3963?; 3947·5?; 3989?; 4013? The pure metal cannot be vaporized except by the arc and spark.* Evidence of this is afforded by the fact that an uncondensed spark yields a very beautiful band spectrum. The lines of silicon have been looked for but not detected in this spectrum.

| Ivory scale numbers. | Description of spectrum. | $\frac{1}{\lambda}$. | λ. |
|---|---|---|---|
| 6<br>20<br>120<br>170 | Continuous band of rays from 6 to 170 strong. Very intense from 20 to 120 | | |
| 96·5 | Lines at . . . . . | 24740 | 4042 |
| 101·7 | ,, . . . . . | 25300 | 3968·3 |
| 102·8 | ,, . . . . . | 25294 | 3953·5 |

## Copper.

Copper foil was heated in the flame. Two silver lines were observed in this spectrum, λ 3383·5 and 3282·1.

| Micrometer measurements in hundredths of an inch. | Description of spectrum. | $\frac{1}{\lambda}$. | λ. | Remarks. |
|---|---|---|---|---|
| 30·3 | The centre of a broad line . . | 18160 | 5506·5 | This spectrum is partly due to CuO apparently. |
| 44·35 | A faint narrow line . . . . | 19684 | 5080 | |
| 167·31 | The centre of a broad line . . | 30398 | 3290 | 3289·9, spark, Hartley and Adeney. |
| 170·76 | ,, ,, ,, . . | 30652 | 3262·5 | 3265·2, 3260·2, two spark lines, Hartley and Adeney. The lines 3290 and 3262·5 are frequently seen in photographs where they would be least likely to be found. |

* This statement is not quite correct. See Appendix (5).

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## Copper Oxide.

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 21·34 | A faint line or narrow band, very indistinct . . . . . | 17125 | 5840 | Feeble ray about 5858 in $CuCl_2$ spectrum, Lecoq de Boisbaudran. |
| | | | | The following measurements are from Lecoq de Boisbaudran "Spectres Lumineux" |
| 22·61 | The same, but a little stronger . . . . . | 17272 | 5790 | Feeble ray about 5696·7 |
| | A continuous spectrum extends from $\lambda$ 5747 to 4280, upon which are several bands superposed, the measurements of which are: | | | |
| 23·71 | The weaker and less refrangible edge of a fairly strong band . . | 17402 | 5747 | |
| 28·34 | The less refrangible edge of a strong band lying upon the foregoing | 17939 | 5577 | Band from 5584 to 5542, about middle 5563 $CuCl_2$, 5545 CuO. |
| 28·8<br>30·0<br>32·0<br>33·5 | There are indications of narrow dark bands at 28·8 and 30, overlying the foregoing also at 32 and at 33·5 | | | |
| 34·91 | The more refrangible edge of the same strong band . . . . . | 18672 | 5356 | Centre of band about 5352 |
| 36·86 | The more refrangible edge of a narrow band overlapped by the foregoing | 18880 | 5296 | |
| 38·8 | The same . . . . . | 19082 | 5241 | 5239 in $CuCl_2$ |
| 40·82 | The same . . . . . | 19298·5 | 5183 | 5194·3 in $CuCl_2$, 5195 in CuO |
| 43·45 | The more refrangible edge of the broad strong line, which is coincident with the more refrangible edge of a weak band continuous with the foregoing bands, which are stronger | 19587 | 5107 | 5106 Cu and CuO |
| 49·2 | The more refrangible edge of a band overlapping the foregoing . . | 20173 | 4957 | 4954 to 4938 CuO |
| 53·34 | ,, ,, ,, ,, ,, ,, ,, ,, . . | 20622 | 4849 | 4867 to 4847 $CuCl_2$ |
| 56·33 | ,, ,, ,, ,, ,, lying upon ,, ,, . . | 20932 | 4777 | 4777 $CuCl_2$ |
| 59·16 | The more refrangible edge of a stronger band overlapping the foregoing | 21225·5 | 4712 | 4704 approximately the less refrangible edge of a nebulous band, $CuCl_2$ |
| 60·17 | The more refrangible edge of a narrower band overlapping the foregoing | 21330 | 4688 | 4690 less refrangible edge of band indefinite and weak, $CuCl_2$ |

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## Copper Oxide—(continued).

| Micrometer measurements in hundredths of an inch. | Description of the spectrum. | $\frac{1}{\lambda}$. | $\lambda$. | Remarks. |
|---|---|---|---|---|
| 62·16 | The more refrangible edge of a narrow stronger band overlapping the foregoing | 21531·5 | 4644 | 4642 $CuCl_2$ |
| 68·2 | The more refrangible edge of a broader and stronger band overlapping the foregoing | 22134 | 4518 | 4522 to 4572 $CuCl_2$ |
| 71·3 | The more refrangible edge of a less diffuse band overlapping the foregoing | 22444 | 4456 | 4453 approximately the middle of the maximum of light of a band, degraded, $CuCl_2$ |
| 75·39 | The more refrangible edge of a less well-defined weaker band . . | 22839 | 4379 | 4369 maximum of light; this is variable. $CuCl_2$ |
| 78·29 | The more refrangible edge of a stronger band overlying the principal band | 23105 | 4328 | 4330 to 4331 $CuCl_2$ |
| 81·1 | The more refrangible edge of a strong broad well-defined line, coincident with the more refrangible edge of the principal strong band extending to this point | 23361·5 | 4280 | 4281 $CuCl_2$ |
| 84·21 | The more refrangible edge of a faint broad line coincident with the more refrangible edge of a fainter band, overlapped by the foregoing band | 23650 | 4228 | 4217 about the more refrangible edge of narrow band of which the middle is at 4233 |
| 92·75 | A very faint line, or faint marking . . . . . | 24412 | 4096 | |
| 93·92 | „ „ „ „ „ . . . . . | 24514·5 | 4080 | |
| 94·63 | „ „ „ „ „ . . . . . | 24576 | 4069 | |
| 95·72 | „ „ „ „ „ . . . . . | 24671 | 4053 | |
| 96·61 | „ „ „ „ „ . . . . . | 24750 | 4040 | |
| 97·29 | „ „ „ „ „ . . . . . | 24809 | 4031 | |
| 98·27 | „ „ „ „ „ . . . . . | 24895 | 4017 | |
| 168·18 | The centre of a broad strong line . . . . . | 30461·5 | 3282 | |
| 171·5 | „ „ „ „ „ „ . . . . . | 30706 | 3256 | |

## Appendix.

[1. Reference has been made to the fact that Mitscherlich ('Pogg. Ann.,' vol. 121, p. 459, 1864) compares the band spectra of metalloid elements with those of compound substances. He used both the oxy-hydrogen and oxy-coal-gas flames. He attributes only line spectra to copper, bismuth, lead, gold, iron, manganese, chromium, tin, potassium, sodium, lithium, zinc, cadmium, mercury, silver, barium, strontium, and calcium. He figures banded spectra of the following elements, magnesium, lines and bands; sulphur, selenium, tellurium, phosphorus, boron, iodine (bromine and chlorine, by absorption), and carbon.

Cyanogen and ammonia are also figured as giving channelled spectra, as well as the following metallic chlorides and oxides :—

PbO, $PbCl_2$, $AuCl_3$, $Fe_2O_3$ or FeO, MnO or $Mn_2O_3$, $CuCl_2$, $CuBr_2$, $CuI_2$, $CuF_2$, and CuO or $Cu_2O$, $BiCl_3$, $BiBr_3$, $BiI_2$, $Bi_2O_3$, BaO, SrO, CaO, $BaF_2$.

The following salts gave lines, or lines and bands together :—

$BaCl_2$, $BaBr_2$, $BaI_2$, $CaF_2$, $CaCl_2$, $CaBr_2$, $CaI_2$, $SrF_2$, $SrCl_2$, $SrBr_2$, $SrI_2$.

It will thus be seen that several metals enumerated on pp. 174 and 179 yield channelled emission spectra, and that these are not credited by Mitscherlich with other than line spectra, except in the case of magnesium, to which he assigns lines and bands. The most refrangible rays observed by Mitscherlich were about λ 4,000, and, though wave-lengths were not determined, the positions of lines and bands were measured and the spectra very carefully drawn.

2. Liveing and Dewar, in their "Investigations on the Spectrum of Magnesium," 'Roy. Soc. Proc.,' vol. 44, p. 243, give the following description of a spectrum ascribed to the oxide or to the process of oxidation :—

The component parts of the spectrum are the following—(1) The *b* group, λ 5183–5172–5166. (2) The MgH series, close to it, 5210, &c., and 5186, &c. (3) Bands in the green. (4) The triplet near L, λ 3838–3831–3829. (5) Triplet near M of the flame of burning magnesium, λ 3730–3724–3720, with the group of bands in that region. (6) The line, λ 2852.

The spectrum which I have described differs from the above inasmuch as the least refrangible ray photographed was λ 3929, which is at the edge of a strong band degraded towards the less refrangible side. Next, there is a strong line and a well-marked band, very strong from 3834 to 3805. Liveing and Dewar place the triplet near L, in or about this region. The triplet near M, and group of bands mentioned above, occupy the place of a band with lines upon it, extending on my photographs from λ 3805 to 3682.

Lines belonging to triplets near L and M were not recognized, though by varying the exposure and using sulphate, nitrate, and carbonate of magnesia, the conditions under which the spectra were obtained were modified. It is possible to obtain an intense continuous spectrum by prolonging the exposure to one hour and using the

nitrate. Strong lines are visible in the continuous spectrum or at its edge. LIVEING and DEWAR obtained their magnesia by burning the metal and holding the ash in the oxy-hydrogen flame.

The line λ 2852 is common to both spectra.

3. As to any possible relation of emission to absorption spectra, it may be remarked that ROSCOE and SCHUSTER found that there was apparently none in the case of sodium and potassium ('Roy. Soc. Proc.,' vol. 22, p. 362, 1874), though the spectra were carefully measured.

LOCKYER and CHANDLER ROBERTS ('Roy. Soc. Proc.,' vol. 23, p. 344, 1875) observed several channelled absorption spectra of metals by volatilizing them in tubes filled with hydrogen. No measurements were made, probably on account of the difficulties involved, and consequently the absorption spectra cannot be compared with channelled emission spectra of the same elements.

Channelled absorption spectra were observed in the vapours of silver, manganese, chromium, antimony, bismuth, and selenium.

Continuous absorption was noticed in copper, cadmium, iron, cobalt, nickel, tin, lead, gold, and palladium.

4. The spectra of sulphur, selenium, and tellurium were carefully investigated by SALET ('Ann. Chim. Phys.' [4], vol. 28, p. 47, 1873; also 'Traité Élémentaire de Spectroscopie,' p. 221), but only so far as the visible region, chiefly the green and blue rays. There are, however, many bands in the spectra of selenium and tellurium, which lie in the ultra-violet region, which appear on my photographs and have been measured.

5. According to a recent photograph, aluminium foil, when burnt, yields a beautiful channelled spectrum.

I have to express my thanks to Mr. HUGH RAMAGE, F.I.C., Assistant Chemist, Royal College of Science, for the care with which he has photographed many of these spectra, and otherwise rendered me valuable assistance.

W. N. H., *Sept.* 29, 1893.]





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## Description of Plates.

Photographs of spectra of the oxy-hydrogen flame, and of various salts, oxides, and metals, heated in the same for a uniform period of one hour. Dispersion used equal to one quartz prism of 60°. Enlarged about two diameters.

### PLATE 6.

1. Oxy-hydrogen flame, water vapour lines.
2. Lithium nitrate, lines of lithium and sodium.
3. Sodium chloride
4. Potassium nitrate
5. Magnesium nitrate
6. Calcium sulphate
7. Strontium sulphate
8. Barium chloride

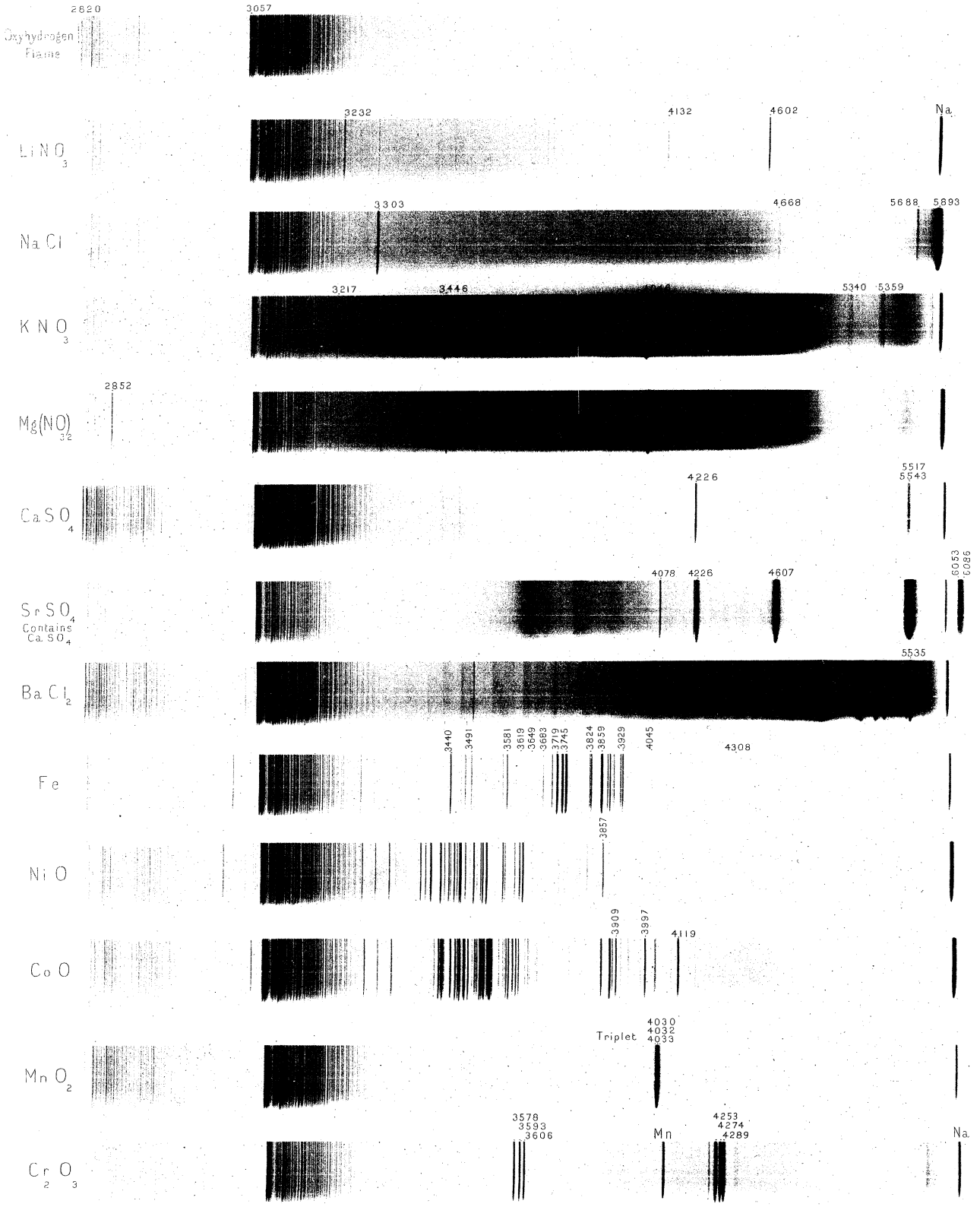
} Band spectra of oxides and chlorides, with line spectra of metals.

9. Iron
10. Nickel oxide
11. Cobalt oxide
12. Manganic oxide
13. Chromium sesqui-oxide

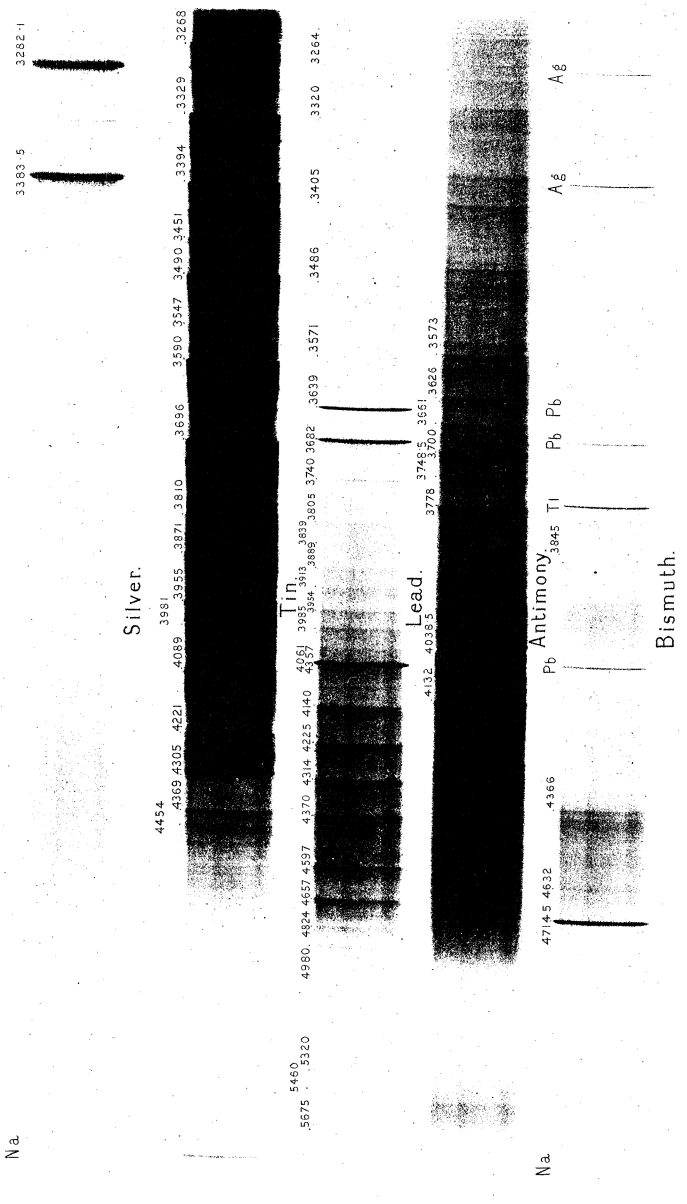
} Line spectra of the metals chiefly.

### PLATE 7.

Band spectra of arsenic, antimony, bismuth, lead, and silver, with a dispersion of four quartz prisms of 60°. Enlarged about two diameters.

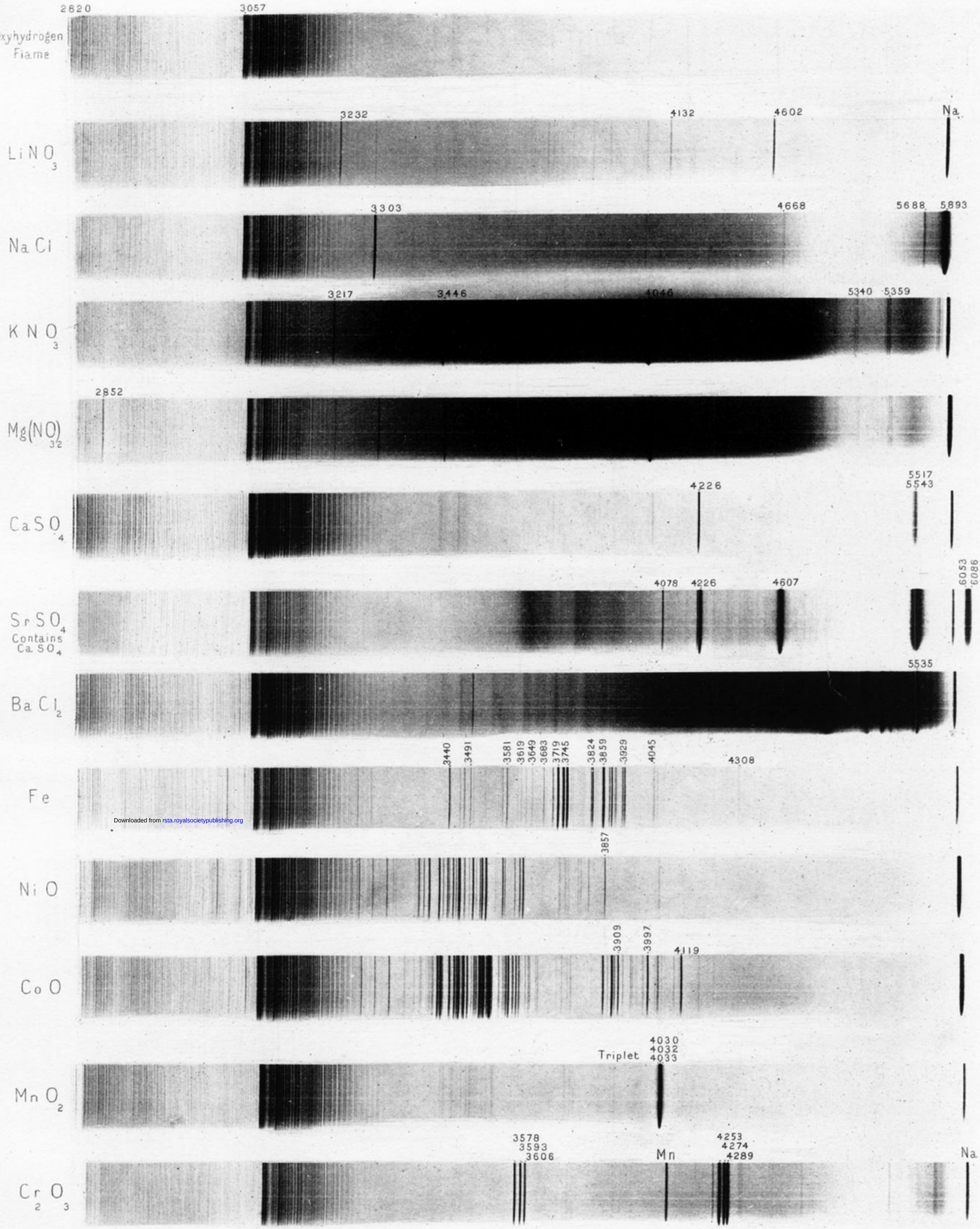



Flame-Spectra at High Temperatures.

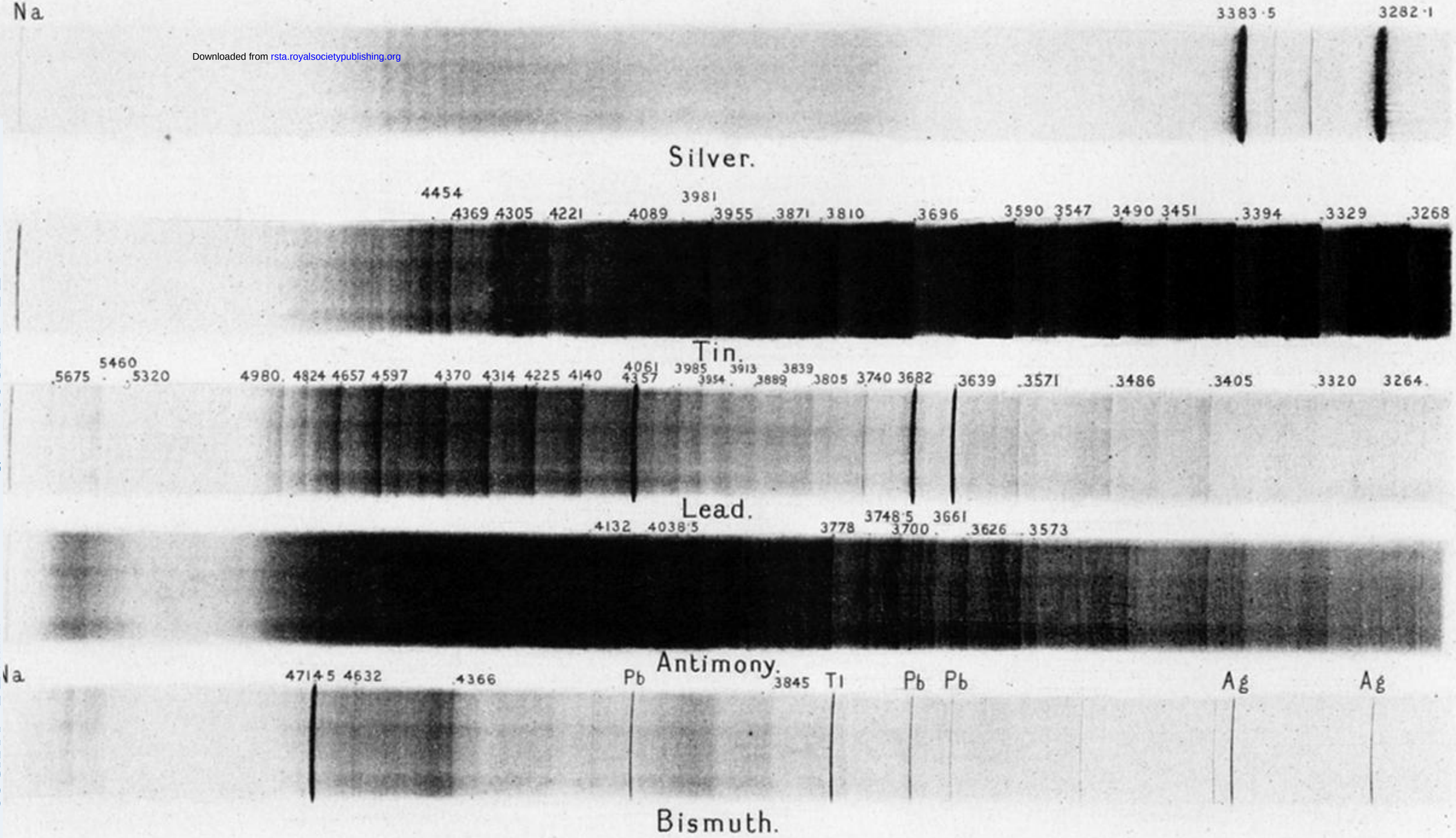



Flame-Spectra at High Temperatures.

Band Spectra of Metals.




Flame-Spectra at High Temperatures.




# Flame-Spectra at High Temperatures.

## Band Spectra of Metals.