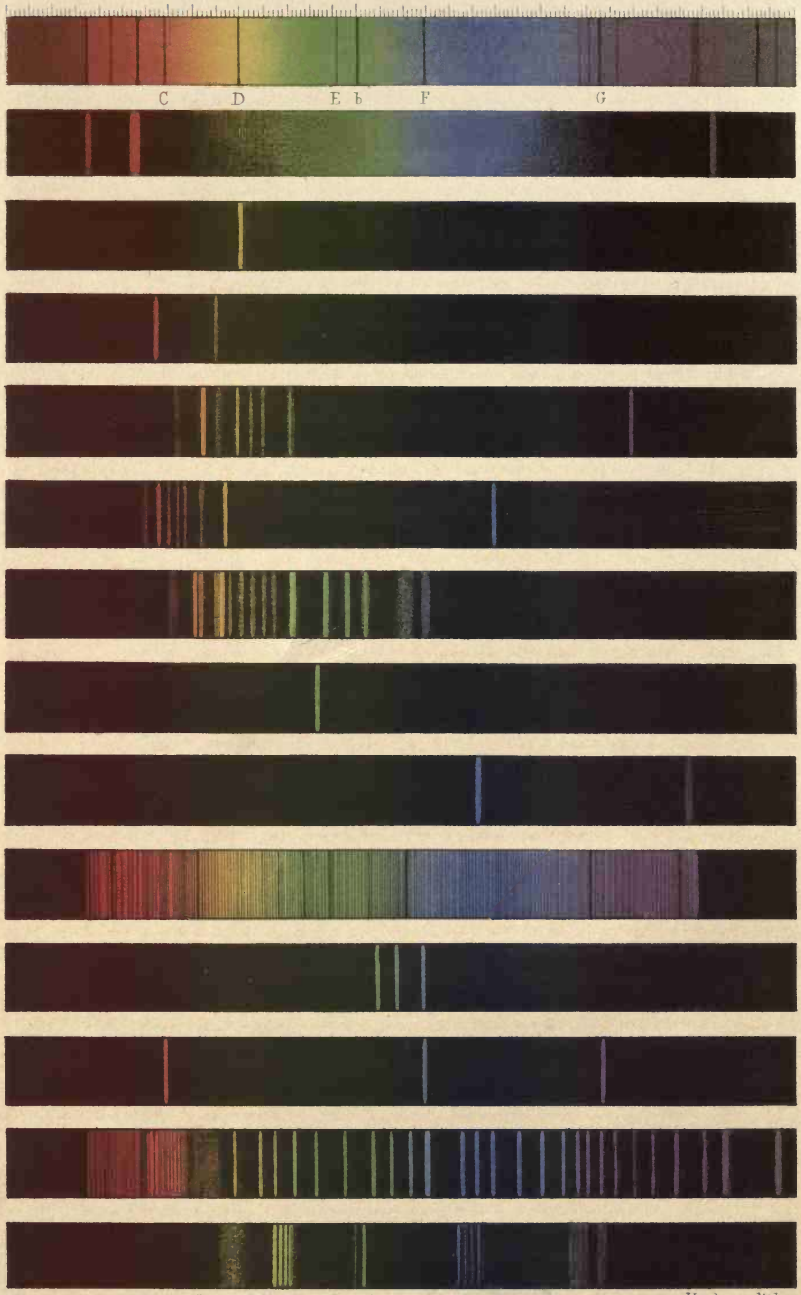
SPECTRUM ANALYSIS

AS APPLIED TO

MICROSCOPICAL OBSERVATION

W. S. SUFFOLK, F.R.M.S.

CHART OF SPECTRA



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ON

SPECTRUM ANALYSIS

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MICROSCOPICAL OBSERVATION.

THE SUBJECT OF A LECTURE DELIVERED AT THE SOUTH LONDON MICROSCOPICAL AND NATURAL HISTORY CLUB, APRIL 9, 1872.

WITH APPENDIX, &c.,
SIX PLATES OF ABSORPTION SPECTRA BY THE AUTHOR,
AND ONE CHROMO-LITHOGRAPH.

BY

W. T. SUFFOLK, F.R.M.S.

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PREFACE.

THE present work is intended as a sequel to the author's course of lectures published in "Microscopical Manipulation." The re-delivery of these lectures at the South London Microscopical Club involved some alteration and extension, the present subject being the most marked addition. As the whole published matter relating to the micro-spectroscope is at present scattered through the pages of various scientific periodicals, it has been thought that the issue of some help to beginners would be welcome. The lecture has been printed almost in the form in which it was delivered, only such alterations being made as were rendered necessary by the absence of lecture table illustrations. The more practical portion has been transferred to the Appendix. The Maps of Absorption Spectra have been drawn and lithographed by the author. No pretension is made to perfect accuracy; this, in the case of many hazy and ill-defined bands, is impossible: only an attempt has been made to represent the appearances of the most characteristic substances: the collection may, however, form the nucleus of a future atlas of absorption spectra.

The Author's thanks are due to Mr. T. G. ACKLAND, Honorary Reporter of the South London Microscopical

Club, for his careful transcript of the subject-matter of the original lecture; to Messrs. WEST's establishment, for the assistance rendered in the execution of the lithographic illustrations; and to Mr. BROWNING, for the opportunity of examining several specimens, and for his kind assistance during the progress of the work.

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ON SPECTRUM ANALYSIS

AS APPLIED TO THE MICROSCOPE.

THE attention of microscopists is in general directed towards the determination of the form and structure of the objects under their consideration. With this view no efforts have been spared to render the instruments of observation as perfect as possible, both optically and mechanically, and to acquire the utmost skill both in the use of the microscope and its accessories, and the preparation of the tissues under examination.

The mode of observation now to be considered furnishes a very delicate means of distinguishing colours, in those particular cases to which it is applicable, the finest sense being mere colour blindness in comparison with the minuteness and precision of spectroscopic determinations.

Very erroneous ideas are prevalent relative to the colour of objects, the popular notion being that the so-called natural colour of a substance is as much a part of it as any of its chemical constituents: this is really not the case, the object being solely dependent for its colour upon its power of absorbing or reflecting certain portions of white light; for instance, an object is red because it absorbs all rays excepting those of that colour, which it reflects, and so produces the sensation known to us as red. A white object reflects all the rays, and appears colourless, because the colours of the spectrum when united produce pure white light, while an object is black because it absorbs all or most

of the light falling upon it. A few simple experiments will render this evident. If a sheet of white paper be illuminated, either by daylight or lamplight, which has had some of the coloured rays removed from it, which may easily be effected by interposing a coloured medium, such as a piece of stained glass, the paper will no longer appear white, because the coloured glass acts as a filter, stopping the passage of certain rays, and only allowing others to pass, —say, for example, red; the white paper under this illumination will appear red, because the light contains no other coloured ray for it to reflect; a piece of black paper would still remain black, because it is incapable of anything else but absorption.

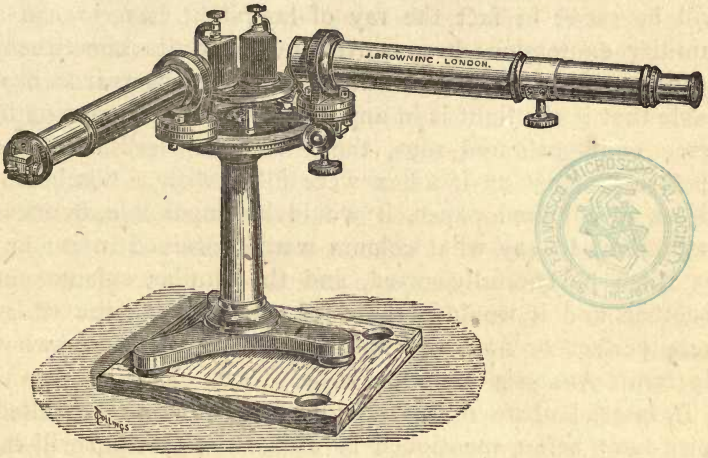
A still more striking result may be obtained by employing a monochromatic light, easily procurable from a spirit-lamp with a large wick which has been well salted: a lamp so arranged will give a flame emitting a pure yellow light. If a number of objects—such as pieces of silk, or paper of various bright colours—be examined by its means, it will be found that all excepting yellow and orange will be totally indistinguishable, simply because the lamp supplies no coloured ray which they are capable of reflecting. Upon submitting the specimens to daylight, or even lamplight, the various colours are readily seen. The effect of this yellow light on the human face is remarkable, it being incapable of developing the carnation and other tints so apparent in health, and giving the most ghastly appearance conceivable to those under its influence. It is from this cause that many colours are distinguished with difficulty by artificial light, the deficiency in the blue and violet rays altering the tint of greens, and rendering some blues and purples grey and even black.

It is well known that when a ray of light is allowed to fall upon a prism it is decomposed, and, owing to the unequal refrangibility of its constituents, the portions least capable of being bent are separated from those which bend more readily, the result being—when received on a screen, after passing through the prism—an elongated band of

variously coloured light, red at the lower end, and passing through orange, yellow, green, blue, and violet, into darkness at the opposite extremity: this coloured band is known as the Spectrum (Frontispiece, Fig. 1).

For its more perfect study instruments have been contrived which are known as spectroscopes (Fig. 1): they vary

FIG. 1.



in detail, according to the purpose for which they are intended, but all agree in consisting of one or more prisms, by which the light is dispersed or spread out,—an adjustable slit, through which a narrow line of light is received, the image of which is caused to fall upon the prism by an

FIG. 2.

achromatic lens known as the collimator, placed at a suitable distance; the spectrum is in most instruments received upon the object-glass of a small telescope, by which it is magnified, and through the eye-piece of which it is viewed. In some, however, as the miniature spectroscope (Fig. 2) and

micro-spectroscope (Fig. 3), it is viewed directly as it emerges from the prisms.

The nature of the indications given by the spectroscope will be most easily understood by referring to a few examples of the appearances presented by variously coloured objects submitted to it.* If the slit is directed to the flame of a lamp or candle, the usual spectrum or band of colour will be seen; in fact the ray of lamplight has, to use a familiar expression, been sorted out into its constituent portions. Now it will at once strike the observer as probable that if the light is in any way defective, or wanting in some of its coloured rays, they will be missed from the spectrum. Just as if a box were filled with a number of pieces of coloured paper, it would be impossible, by mere inspection, to say what colours were contained in it; but let them be carefully sorted, and the similar colours put together, and it would at once be seen whether the series were perfect or not; and this is, in a broad sense, what Spectrum Analysis really shows us.

If, instead of an ordinary lamp or gas flame, the salted spirit-lamp before mentioned be used, the spectrum will be found to consist only of a narrow bright yellow line (Frontispiece, Fig. 3): the spectroscope has shown at once that this flame emits light of one colour only. If a platinum wire, with a small quantity of any salt of lithium, be placed in the flame, another line (Frontispiece, Fig. 4) will make its appearance, but in this case† lower in position, and of a bright crimson: this will take place even if the amount of lithium be so small as to produce no change perceptible to the eye in the colour of the yellow flame.

To anticipate the explanation, the yellow light is caused by the sodium of the salt in the state of incandescent gas,

* The whole of these experiments may be performed with one of the small pocket or miniature spectroscopes (Fig. 2); also, but hardly so conveniently, with the spectroscope attached to the microscope, as it is somewhat difficult to direct the mirror to the part of the flame influenced by the burning material.

† That is, nearer the red end of the spectrum.

and is known to be characteristic of the presence of that metal; the red line is an equally certain indication of lithium. So delicate is this test that the sodium spectrum is always produced, even without actually placing any soda salt in the flame, there being always sufficient floating in the atmosphere, and otherwise distributed, to give a marked indication of its presence.

As a general rule solid substances, when incandescent, give a continuous spectrum, such as that of lamplight or a white-hot platinum wire, the light of gas or a lamp being chiefly due to incandescent particles of carbon in the flame; on the contrary, incandescent gases give a spectrum consisting of bright lines only, as already seen in the spectrum of the incandescent vapours of sodium and lithium; it will be found that every substance capable of volatilisation gives its characteristic bright line or lines, by which it can be readily identified. Thus potass (Frontispiece, Fig. 2) gives a very distinct red line lower than that of lithium, and a line far up in the violet; there is also another very faint red line, but this is seen with difficulty: this affords a very ready means of distinguishing potassium from sodium salts. If the flames of the ordinary red or green fire be examined with the spectroscope, they will be found to give the spectra of the metals strontium and barium (Frontispiece, Figs. 6 and 7 respectively), mixed, however, with those of potassium and sodium,* and some other substances. Or the chlorides of strontium, barium, or calcium (Fig. 5), may be placed on a platinum wire in the flame of a Bunsen burner, which gives a more intense heat than that of a spirit-lamp, and, being thus volatilised, their spectra obtained.

* Red and green fires, capable of being burnt in a room with the minimum of inconvenience may be made as follows:—

Red.		Green.	
Nitrate Strontia ..	9 parts.	Nitrate Baryta ..	9 parts.
Chlorate Potass ..	1½ „	Chlorate Potass ..	1½ „
Shellac	3 „	Shellac	3 „

The shellac to be in the state of coarse powder. The nitrate of strontia should be well dried before using.

Spectrum Analysis has led to the discovery of four new metallic elements, viz., cæsium and rubidium, by Bunsen, in 1860; thallium (Frontispiece, Fig. 8), by Crookes, in 1861; and indium (Frontispiece. Fig. 9), in 1864, by Reich and Richter.

If an electric spark is passed through a tube of any gas in a very attenuated condition, it will follow the usual rule, and give a spectrum consisting of bright lines (Frontispiece, Figs. 12, 13, and 14), representing the spectra of hydrogen, nitrogen, and coal-gas. The nebulæ, upon being examined with the telespectroscope, give gaseous spectra (Fig. 11).

The spectrum of daylight (Frontispiece, Fig. 1) is a very remarkable one; like that of lamplight, it exhibits a series of colours from red to violet, but is crossed by numerous fine black lines. These were first observed by Dr. Wollaston in 1802, and more completely examined by Frauenhofer in 1814, who mapped as many as 576 of them. The number at present known is considerable; the precise number is undetermined. The more conspicuous of these lines were distinguished by Frauenhofer by some of the letters of the alphabet:—A at the commencement of the red; *a*, B, and C in the brighter portion of the red; D between yellow and orange; E and *b* in the green; F at the beginning of the blue; G in the violet; and H near the termination of the visible spectrum.* The cause of these black lines was unknown until the discovery by Kirchhoff, in 1859, that vapours in a comparatively cool state had the power of absorbing the light emitted by the same gases when incandescent. Frauenhofer had observed the exact coincidence of the yellow line of sodium with the D line of the solar spectrum (Frontispiece, Figs. 1 and 3), but this had led to no result until Kirchhoff had succeeded in "*reversing*" the sodium line. While experimenting with a view of verifying the exact coincidence of these lines, he placed the sodium flame before the slit of the spectroscope with which sunlight

* These principal lines are placed at the head of each plate in the Appendix.

was being observed, and found that the D* lines were seen with increased blackness. The next step was to use the lime-light, which gives a continuous spectrum, instead of sunlight; and upon allowing it to shine through the sodium flame, it was found that the black D lines made their appearance.

The reversal of the sodium line is most easily demonstrated by burning a piece of sodium in an iron spoon; when first ignited it gives only the well-known yellow line, but as the metal becomes hot and begins to glow, a continuous spectrum is seen, and the surrounding vapour will absorb the yellow line, producing a strong black one in its place.

The discovery of the nature of one of these lines led to experiments with metals and other substances, with the result that the bright lines of many of them were identified with black lines in the solar spectrum, 460 of these lines alone corresponding with those of the spectrum of iron, and 16 metals altogether having been distinguished in the sun.†

The fixed stars yield continuous spectra crossed with fine black lines resembling those of the solar spectrum, but differing in the number and arrangement of the lines; many of these have been observed and mapped, and in the case of Sirius (Frontispiece, Fig. 10) have led to some remarkable discoveries; their consideration, however, belongs rather to the department of the astronomer than to a rudimentary treatise on the application of the spectroscope to work of the microscopist.

The solar spectrum is of interest to the microscopist, chiefly on account of the fixed nature of the dark lines, the principal of which, as distinguished by letters, serve as

* The D line is separated into two when an instrument of sufficient dispersive power is used.

† For a familiar account of Spectrum Analysis, see Lecture by Professor Roscoe, F.R.S., delivered at Hulme Town Hall, Manchester, Nov. 9, 1870; and Lecture on "Spectrum Analysis in its Application to the Heavenly Bodies," by Dr. Huggins, F.R.S., at same place, Nov. 16, 1870. Heywood, Manchester, and F. Pitman, Paternoster Row, London. Price 1d.

marks to indicate certain parts of the spectrum, with which the position of the absorption-bands, presently to be mentioned, can be readily compared, and from which measurements can be taken, so that it can be stated that a band coincides with C or D, or other Frauenhofer line, or is a certain distance from them. This is of great importance, because the colours of the spectrum are so blended that it is impossible to distinguish the place where one ends and the next begins.

The solar spectrum has an additional claim to our attention as an example of an absorption spectrum, the only class of spectra yielded by objects under the microscope. Absorption spectra differ materially from those hitherto considered, the examination of the light from incandescent metallic and other vapours has been the analysis of emitted light; the result as viewed through the spectroscope being bright lines, which have enabled certain substances to be identified. In microscopical investigations with the aid of the spectroscope the light has been subject to certain modification, either by transmission through the substance examined, or by reflection from its surface, and instead of bright lines being produced, portions of the spectrum are absent, sometimes as indefinite hazy shadows (Plate IV., Figs. 31 to 36), and at others more or less clear and well-defined bands (Plate I., Figs. 1, 5, and 6). They do not, however, proceed from the same cause as the Frauenhofer lines, namely the absorption of emitted light by vapours, but are probably owing to the incapability of the transmitting media of allowing light of certain colours to pass, or in the case of opaque objects, only certain portions are reflected, and these alone are seen in the spectrum. The causes of these singular appearances are at present unknown, but many of the spectra are constant, and characteristic of the colours of certain substances. The absorption spectra most studied have been those of blood; attention was first called to the peculiar absorption of blood by Professor Stokes.* The

* "Proceedings of Royal Society," xii., p. 353.

bands given are extremely characteristic, several distinct spectra being given by blood in different conditions (Plate VI., Figs. 51 to 56), and as strong indications can be obtained even from very dilute solutions, the spectrum test for blood is considered the most delicate within the power of the analyst. When sufficiently large quantities of coloured substance are procurable, an ordinary spectroscope will suffice for conducting the examination; but as the amount of material at our disposal is frequently very small indeed, the microscope becomes of service, by collecting the light from the small object on the stage, just as the telescope enables spectrum observations to be made of the light of the sun or stars. So efficient is the micro-spectroscope for this purpose, that a distinct indication may be obtained from a single blood corpuscle dried on a slip of glass, or the contents of the stomach of a flea, or even a dried bloodstain on a piece of linen or paper. Spectrum analysis applied to microscopical investigations has as yet done little in comparison with the vast discoveries to which it has led the chemist and astronomer; this principally arises from the subject being at present almost unworked; the observers are few, and the laws causing the various absorptions are as yet unknown. A few dark lines and bands viewed in the micro-spectroscope may seem very trivial and unimportant, and the inquiry may very naturally arise as to the good that may be expected to arise from a subject which appears to be so unpromising. But a document may be of value although we cannot at once read the language in which it is written, because at some time we may be able to do so. These shadows and lines may be equally important; a few lines and dots printed on a slip of paper are delivered by a telegraph instrument, and yet these may be an important communication from the other side of the Atlantic. When we learn to read the meaning of our spectral lines by understanding the laws which regulate their production, we may expect equally important information relative to some of the secrets of nature with respect to colour, and possibly molecular structure. The key is

needed, and this can only be discovered by diligent work. Much has already been done by Mr. H. C. Sorby, Dr. Thudicum, and Mr. E. Ray Lankester, and their valuable researches will aid the enquiries of workers in the same field; more observers are, however, needed to thoroughly investigate a subject which at present may be spoken of as almost entirely unexplored.

APPENDIX.

APPARATUS EMPLOYED IN VIEWING AND MEASURING THE SPECTRA OF MICROSCOPIC OBJECTS.

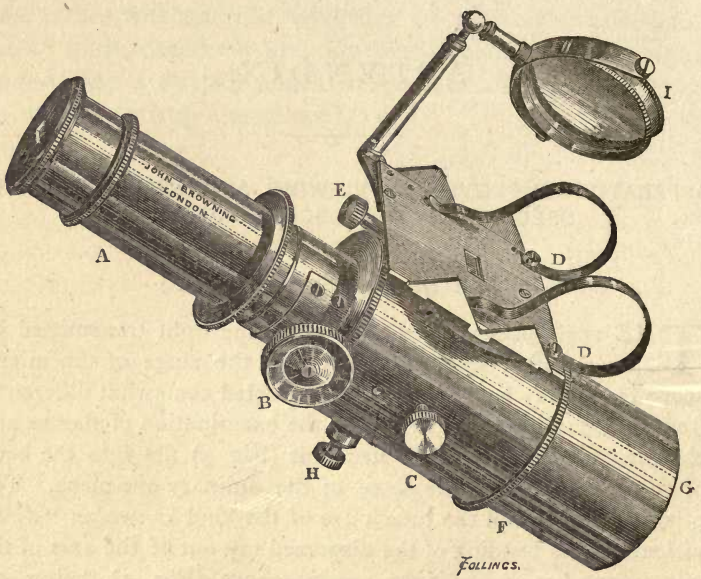
The Micro-spectroscope.

THE spectroscope used to analyse the light transmitted by or reflected from an object upon the stage of the microscope is, as may be supposed, constructed somewhat differently from that used by the chemist for the examination of flames and electric discharges. The instrument (Fig. 3) fits into the body of the microscope in the place of the ordinary eye-piece. The prisms contained in the tube A are of the kind known as "*direct vision*." The bending of the dispersed ray out of the axis of the microscope, as in ordinary spectroscopes (Fig. 1), being extremely inconvenient. The prisms are represented in section in Fig. 5, P, and consist of two prisms of very dispersive flint-glass between three of crown placed in an opposite direction; the separation of the line of light passing through the slit is effected by the two flint prisms, the others being employed for the purpose of bringing the ray back into a straight course.* The tube A fits on to a tube having a range of motion by means of a slide and rack and pinion, B, which permits the prisms and eye-glass to be adjusted so as to focus the various parts of the spectrum. The slit is placed in the focus of the eye-glass in the usual position of the diaphragm; it can be opened or closed by the screw with the milled head, H. The screw C determines the width of the spectrum, and is useful when the object is too small to fill up the entire aperture of the diaphragm; the field glass occupies the position indicated by F, and the tube G fits into the

* Some spectroscopes have been made with only three prisms, the middle one being of sufficiently dense glass to effect the required amount of dispersion.

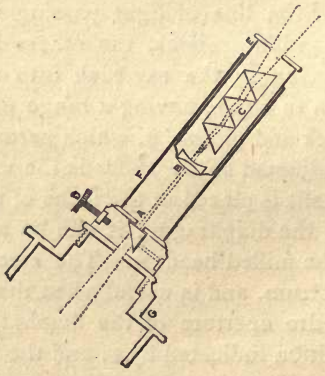
draw-tube of the microscope. For obtaining a second spectrum for purposes of comparison, a stage, D, is attached to one side

FIG. 3.



of the eye-piece, and communicates with the interior by means of an aperture in its centre: the light entering is received by a

FIG. 4.



right-angled prism covering one-half of the slit (Fig. 4, A), and reflected upwards, parallel with that passing through the body of the microscope; and the two spectra are seen side by side.

The object is held upon the stage by the two springs, D, D, and tubes are secured by being pressed by the same springs into two notches projecting from its sides. Light is reflected through the object by a mirror, I, furnished with suitable adjustments, and the aperture can be closed by a shutter acted upon by the screw E, when it is wished to exclude the light forming the second spectrum.*

When the spectrum of a microscopic object is to be examined, the spectroscope is substituted for the ordinary eye-piece. The tube, A, containing the prisms is removed, and by means of the screws C and H the slit is opened to its greatest extent, which will enable the object to be seen through the slit: the field is then to be reduced in width, if necessary, by the screw C, so that no light passes through the slit which has not been transmitted by the object: if care is not taken on this point the spectrum will be much interfered with by extraneous light, and the result will be vitiated.

When large objects, such as solutions in tubes or in the cells (Figs. 6 and 7) are examined with low powers, the spare tube of the binocular may be advantageously employed as a "*finder*," the prism being pushed in so as to permit the passage of the light up the inclined body. When the object is brought into field the prism can be withdrawn, and the whole of the light allowed to pass through the right hand body carrying the spectroscope: this will often save much time, but where there is doubt about the image of the object filling the slit, the placing in field is best done with the eye-piece of the spectroscope.

The tube A is now placed in position and the spectrum viewed, the slit being closed by the screw H until the absorption-bands are well defined; the aperture required is dependent upon the nature of the object and the amount of light: after a little practice no difficulty will be experienced in making the best adjustment. To obtain a clear view of absorption-bands or lines care must be taken to focus accurately by means of the rack and pinion, B, as lines in different parts of the spectrum are not in focus together. It is also necessary to throw the object slightly out of the focus of the object-glass of the microscope, otherwise dark lines will be seen running through the length of the

* In some recently constructed micro-spectroscopes, two studs, on either side of the tube, are advantageously substituted for the screw F.

spectrum: these are caused by various points of the object being elongated by the dispersive power of the prisms: similar appearances are produced by particles of dirt adhering to the edges of the slit.

Tubes containing solutions and other objects can be placed on the stage, D, and examined by means of light reflected by the mirror, I, and their spectra compared with those obtained through the object-glass of the microscope.*

When the spectrum of an opaque object is required, it should be very strongly illuminated with the condensing lens, or, still better, with the parabolic lieberkuhn, which gives a light of much greater intensity. Lamplight is in general to be preferred to daylight, as the Frauenhofer lines are sometimes apt to be mistaken for lines belonging to the spectrum under examination; in certain cases, however, strong daylight is to be preferred,—for instance, in viewing absorption bands at the violet end of the spectrum. The most intense lamplight is obtained by the combustion of camphine in a specially constructed lamp;† paraffin lamps, however, answer very well. More powerful illumination can be obtained by placing a bull's-eye or other condenser between the lamp and mirror, or by the use of an achromatic condenser; those of the eye-piece construction, such as the "Webster," are to be preferred, on account of the large size of their lenses.

When there is a difficulty in passing the light through the object, on account of its semi-opacity, as in the case of turbid solutions, the lime-light may be employed with advantage.

When the object-glass is of large aperture, the spectrum is much improved by a cap, having a central aperture of about the sixteenth of an inch, being placed over it: this will exclude much extraneous light, which would otherwise interfere with the spectrum. A minute aperture, about 1 millimetre in diameter, on the stage, accurately centred, will also aid in securing a pure spectrum.

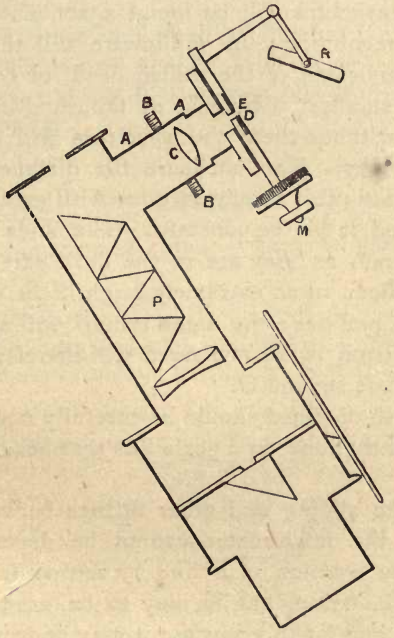
* For two forms of micro-spectroscopes for use with the binocular microscope, see "Proceedings of the Royal Society," vol. xv., p. 433 (H. C. Sorby), and same work, No. 112, p. 443 (Wm. Crookes); and "Monthly Microscopical Journal," vol. ix., p. 1 (E. J. Gayer).

† "Microscopic Manipulation," p. 26.

Micrometers.

For measuring and registering the position of absorption-bands with the micro-spectroscope, the best arrangement is the "*Bright-line Micrometer*,"* represented in section (Fig. 5). A lateral piece, A A, is attached to the upper part of the prism tube; at its outer extremity is an oblong box containing a glass plate, upon which is photographed a minute figure of X, bright on a dark ground: this is moved vertically by means of a screw

FIG. 5.



connected with the graduated head, M; the cross is illuminated by the small plane metallic mirror, R, and its image formed by the lens, C, capable of being adjusted for focus by the milled collar, B. This image is reflected to the eye of the observer from the face of the upper prism, which must be inclined at an angle of 45°, and is viewed along with the two spectra, between which it appears to pass when the milled head, M, is turned.

* "Monthly Microscopical Journal," vol. iii., p. 68.

For micrometrical purposes the prisms should be of as great dispersive power as is consistent with a good view of most absorption bands.

To adjust the micrometer a bright day should be selected, so that the Frauenhofer lines in the solar spectrum may be distinctly visible.

Notice how many revolutions of the milled head, M, will carry the X through the whole length of the spectrum: this will vary according to the dispersive power of the prisms. In the instrument used in constructing the spectrum maps in this work, ten revolutions measured the required distance. In constructing the maps a centimetre will be found a convenient measure to represent one revolution; the millimetre will then equal 10 of the smallest divisions of the milled head, or 1-10th of a revolution: these smallest divisions, or thousandths, need not be regarded, as without them the spectrum will be divided with sufficient accuracy. Next measure the distances between the Frauenhofer lines: this should be done with great care, as when once determined it will be constant. The lines A and *a* need not be measured, as they are in the dark part of the red, and are only to be seen in an extremely bright light, and will hardly be required in practice: the same remark will apply to the line H. The spectrum to be measured will therefore extend from about B to a little beyond G.

The results so obtained should be carefully noted: this can be most conveniently done on a scale like that heading each of the plates.

Owing to the sliding and other fittings between the prisms and the slit, the micrometer cannot be depended upon for pointing to the position of a line by setting it to the number recorded on the scale, but is only to be used for measuring between lines, and for this purpose it may be trusted.

For measurements, when daylight is not to be obtained, the following fixed marks are useful:—

The D line can be produced as a bright line from the flame of a spirit-lamp with a salted wick (Frontispiece, Fig. 3). Lithium will give a bright red line, situated between B and C (Frontispiece, Fig. 4): its distance from these lines should be measured and mapped, so that it may be used for their determination. A solution of chloride of cobalt in chloride of calcium (Pl. 1,

Fig. 6)* gives a spectrum of three bands; the upper edge of the broad band nearest the red coincides with the C line. A solution of nitrate of didymium (Pl. 1, Fig. 1) gives six sharp narrow bands, well distributed through the spectrum, and all conveniently near some of the solar lines: the first, commencing at the red end, is a little above D; the upper edge of the second is midway between E and *b*; the lower edge of the third is coincident with *b*; the fourth is near F; the other two between F and G.† These two solutions with sodium and lithium will be found to give a sufficient number of fixed points, when compared with the Frauenhofer lines, to allow spectra to be accurately mapped by artificial light.

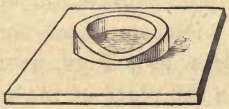
The greatest care should be taken to focus the X by means of the collar, B, so that it is sharply defined, otherwise it will shift its place when the eye of the observer moves, and cause serious errors from parallax.

Cells.

For the examination of coloured fluids two kinds of cells will be found useful:—

Wedge-shaped Cells (Fig. 6).—These give a gradually increasing depth of fluid, and consequently gradation of tint, so that the intensity of colour giving the best spectrum is readily

FIG. 6.



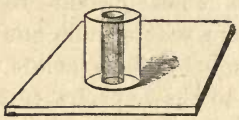
found by sliding the cell before the object-glass: when the dispersive power of the wedge is found to be objectionable, it can be neutralised by the use of an equivalent wedge of glass as a cover.

* This and other solutions in tubes may be obtained of Mr. J. Browning.

† The absorption bands of nitrate of didymium are inserted on the scale heading each map, along with the Frauenhofer lines, from which they are distinguished by their occupying only one-half the width of the spectrum, and their greater breadth; the lithium line has also been mapped, and is marked Li.

Deep Cells (Fig. 7).—These are cut from barometer tube, and made of various depths: the interior diameter should be small enough to permit the tubes, when filled, to be inverted without the fluid running out. These narrow cells are extremely useful when only a small quantity of a substance is available for

FIG. 7.



examination, as a considerable depth of fluid, and consequent intensity of colour, may be obtained with the minimum of material. If a less degree of colour is required the cell can be turned on its side, and the fluid viewed through the walls of the tube.

The points to which attention is to be directed, in observations with the micro-spectroscope, are—the character, position, and number of the absorption-bands, and also, in some cases, the changes produced by the use of reagents.

As before mentioned, the spectra viewed by the micro-spectroscope are all negative; they are the spectra of deficiencies in the light examined, and not of emitted light. These deficiencies manifest themselves in various ways: as a general rule the absorption is in the complementary portion of the spectrum; *e.g.*, a red medium may be expected to obscure more or less of the green, a blue or violet to show some obscuration of the orange or yellow (Plate IV., Figs. 31 to 36). These aniline colours differ merely in the place of the absorption: its amount can be increased or diminished at pleasure by varying the intensity of the tint, either by dilution or giving a greater or less thickness to the coloured medium through which the light is caused to pass. Hazy, broad, and undefined bands of this description are the most common of spectral indications, and at the same time the most unsatisfactory: the majority of colours obtained from the petals of flowers are of this description, such as *Centaurea cyanus* (Plate V., Fig. 49). Such absorption is known as "*general*."

Other media give well-defined bands, more or less sharp, and sometimes as narrow as some of the larger Frauenhofer lines.

Nitrate didymium (Pl. I., Fig. 1); didymium glass (Fig. 3), the hair-like band between C and D; solution of chloride of cobalt in chloride of calcium (Fig. 6); fine line between 1st and 2nd bands; parisite (Pl. III., Fig. 27); fine line between C and D, and many others;—such spectra are always characteristic, and are the most positive indications given by the instrument. The character of the absorption is greatly affected by the employment of reagents. A weak alcoholic tincture of alkanet root gives a pink solution. The spectrum shows three bands (Pl. III., Fig. 28), upon adding a minute quantity of carbonate of soda another band lower down makes its appearance (Fig. 29), and when an excess of the reagent is used the two other bands fade away, the solution having gradually become blue.

The effect of similar treatment in the case of the blue tincture from the petals of *Lobelia speciosa* is seen in (Pl. V., Figs. 45, 46) the blue solution in this case becoming green.

A very full account of the changes produced by reagents on the colouring matter of flowers, full directions for their employment and a provisional classification of vegetable colours will be found in a paper by Mr. H. C. Sorby, F.R.S., "On a Definite Method of Quantitative Analysis of Animal and Vegetable Colouring Matter by means of the Spectrum Microscope" ("Proceedings Royal Society," vol. xv., p. 433). This paper may be consulted with advantage by all who wish for information on the mode of conducting micro-spectroscopic observations. Spectra may often be obtained from the petals of flowers with the micro-spectroscope, by viewing them by means of a strong transmitted light; some petals may be dried and mounted in balsam. Alcoholic solutions of vegetable colours are in general very fugitive, that of the petals of *Digitalis purpurea* (common foxglove) faded sensibly during a few minutes' exposure to daylight. A solution of chlorophyl from grass, after three hours' exposure to condensed lamplight, lost some of its absorption bands. All such specimens should, therefore, be examined, and their spectra mapped as speedily as possible.

The various appearances presented by blood under the spectroscope may be studied with advantage; 16 blood spectra are figured and described by Dr. Thudicum*; the absorption bands

* "Tenth Report of the Medical Officer of the Privy Council, 1867." Appendix No. 7, pp. 218 to 233. Plate I. and Plate II., Figs. 1 to 3.

as represented in his chromo-lithographs must, however, be taken in conjunction with the intensity diagrams in the text, as the whole extent of the absorption is indicated by solid black without any gradation of tint. Many of Dr. Thudicum's preparations are obtained by complex and difficult processes, which may be repeated, and his observations studied by those who wish thoroughly to study the various colours exhibited by blood under different conditions.

As a practical exercise for the beginner, six blood spectra, those the easiest to obtain, have been selected; they are represented in Pl. VI., Figs. 51 to 56. A small quantity of fresh blood diluted with water, which may conveniently be examined in one of the deep narrow cells (Fig. 7), will absorb in two places, the lower band at the termination of the orange is narrower, darker, and better defined than that in the green, which is broader and hazy; this is the spectrum of the colouring matter named by various authors cruorine, hæmoglobin, and hæmatocrystalline. The bands to the beginner may somewhat resemble those of turacine (Plate IV., Fig. 39) and carmine (Fig. 40), but upon comparison the bands of fresh blood will be seen to be of unequal width and intensity, and their position to be lower than those of either turacine or carmine. Next add a minute portion of the double tartrate of potass and soda, and when this is dissolved a minute fragment of protosulphate of iron and ammonia, upon stirring, which is most conveniently done with a platinum wire flattened at the end, and turned up like a small hoe. The two original bands will disappear, and the spectrum of reduced hæmoglobin (Plate VI., Fig. 52) will be seen, consisting of one broad hazy band. Upon adding citric acid to another portion of diluted blood a band makes its appearance in the red (Plate VI., Fig. 53), and the rest of the spectrum is much obscured; with a very strong light two other bands may be distinguished in the darkened portion, one a little below E, and the other between *b* and E, but under ordinary circumstances the spectrum will be seen as Fig. 53; upon deoxidising as before, two bands in the green will be seen (Plate 6, Fig. 54); these differ from those in the spectrum of fresh blood, not only in their position, but also in their breadth and intensity, the lower one being broader than that of fresh blood, and the upper one being narrow and faint.

Blood acted upon by sulphuric acid becomes altered, and another

colouring matter produced, cruentine (Thudicum, Plate VI., Fig. 56); when rendered alkaline the spectrum (Plate VI., Fig. 55) is seen. Dr. Thudicum figures eight varieties of cruentine spectra.

For the detection of blood-stains when altered by time or admixture with other substances, see paper "On some Improvements in the Spectrum Method of Detecting Blood," by H. C. Sorby, F.R.S., "Monthly Microscopical Journal," vol. vi., p. 9.

LIST OF PAPERS, &c. RELATING TO ABSORPTION SPECTRA AND THE MICRO-SPECTROSCOPE.

The following List may be useful, although it is by no means complete:—

BRIDGE, H. G.—"Mapping with the Micro-Spectroscope, with the Bright-line Micrometer."
Month. Micro. Journ., vi., 224.

BROWNING, J.—"On a Method of Measuring the Position of Absorption Bands with a Micro-Spectroscope."
Month. Micro. Journ., iii., 68.

BUNSEN, R.—"Ueber die Umkehrung des Absorptions Spectra des Didyms."
Chem. Pharm., cxxxi., 255.

,, "Ueber die Absorptions Spectra der Didymsalze."
Pogg. Ann., cxxviii., 100.

CROOKES, W.—"On some Optical Phenomena of Opals."
Proc. Roy. Soc., 1869, 448.

,, ,, "On a New Arrangement of Binocular Spectrum Microscope."
Proc. Roy. Soc., 1869, 443.

DEAS, F.—"On Spectra Formed by the Passage of Polarised Light through Double Refracting Crystals seen with the Microscope."
Month. Micro. Journ., vi., 135.

GAYER.—"On a New Form of Micro-Spectroscope."
Month. Micro. Journ,, ix., 1.

GLADSTONE, J. H.—"On an Optical Test for Didymium."
Chem. Soc. Journ., x., 219 (1858).

GLADSTONE, J. H.—"On the Use of the Prism in Qualitative Analysis."
Chem. Soc. Journ., x., 79 (1858).

HEREPATH, W. B.—"On the Use of the Spectroscope and Micro-Spectroscope in the Discovery of Blood Stains," &c.
Chemical News, vol. vii., 113 and 123.

HORNER, C.—"On the Presence of Didymium in Certain Specimens of Pyromorphite."
Chemical News, Dec. 13, 1872.

HOPPE, F.—"On the Absorption Lines in the Blood Spectrum."
Schmidt's Jahrbuch d. ges. Med., cxiv. (1862).

HUGGINS, WILLIAM.—"On the Prismatic Examination of Microscopic Objects.
Quart. Journ. Micro. Soc., July, 1865.

LOMMEL, Prof.—"Chlorophyl in its Relation to Light."
Chemical News, Sept. 13, 1872.

LANKESTER, E. R.—"On Blue Stentorin—the Colouring Matter of *Stentor cæruleus*."
Quart. Journ. Micro. Sc., April, 1873.

MOSELEY, H. N.—"On Actinocrome, a Colouring Matter of Actiniæ, which gives an Absorption Spectrum."
Quart. Journ. Micro. Sc., April, 1873.

ROOD, O. N.—"On the Didymium Absorption Spectrum."
Silliman's Journal, 2nd series, xxxiv., 129.

SORBY, H. C.—"On the Application of Spectrum Analysis to Microscopical Investigations, and especially to the Detection of Blood Stains"
Chemical News, xi., 186, 194, 232, 256.

" "On a Definite Method of Qualitative Analysis of Animal and Vegetable Colouring Matters by means of the Spectrum Microscope."
Proc. Roy. Soc., xv., 433.

" "On a New Micro-Spectroscope, and on a New Method of Printing a Description of Spectra seen with the Spectrum Microscope."
Chemical News, xv., 220.

SORBY, H. C.—"On a New Element Accompanying Zirconium."
Chemical News, xix., 121.

„ "On some Technical Applications of the Spectrum Microscope."
Quart. Journ. Micro. Sc., ix., 358.

„ "On the Various Tints of Autumnal Foliage."
Quart. Journ. Sc., vol. i., p. 64.

„ "On some Improvements in the Spectrum Method of Detecting Blood."
Month. Micro. Journ., vi., 9.

„ "On the Examination of Mixed Colouring Matters with the Spectrum Microscope."
Month. Micro. Journ., vi., 124.

STODDART, W. W.—"Application of Spectral Analysis to Pharmacy."
Pharmaceutical Journal, vol. xi., p. 132.

THUDICUM, Dr.—"Researches Intended to Promote an Improved Chemical Identification of Diseases."
10th *Rep. Med. Officer Privy Council*, 1867.

DESCRIPTION OF PLATES.

FRONTISPIECE.

1. Solar Spectrum, with a few of the Principal Lines.

2. Potassium. Gives two characteristic lines: one, Ka.α, in the extreme red near the line A; another, Ka.β, in the violet. A third line, near B, is to be seen only when the light is very intense: this line is much too distinct in the figure.

3. Sodium. One line, Na.α, which appears double in instruments of sufficient dispersive power, and is exactly coincident with D. Four other lines, not shown in the figure, are visible when the temperature is sufficiently high.

4. Lithium. The characteristic line Li.α is situated in the red between B and C; Li.β, in the orange, is a faint line, only seen at a high temperature.

5. Calcium. Two characteristic lines, Ca.α in the orange, and Ca.β, bright green: the other lines are less evident.

6. Strontium. Characterised by the absence of green bands. Eight lines are remarkable in this spectrum, viz., six red, one orange, and one blue. The orange line, Sr.α, is a little lower than D; two of the red lines, Sr.β and Sr.γ, and the blue line, Sr.δ, are the most important: the last requires a high temperature: it is easily seen in the red fire of the pyrotechnist, accompanied, however, with the lines of potassium, sodium, &c.

7. Barium. Easily distinguished by the green lines, Ba.α and Ba.β, and in this respect contrasting strongly, as might be expected from the colour of the flame, with the preceding: many other lines, of less brilliancy, are to be seen in this very complicated spectrum. Barium is the colouring constituent of green fire.

8. Thallium. One bright green line, impossible to be mistaken for any other.

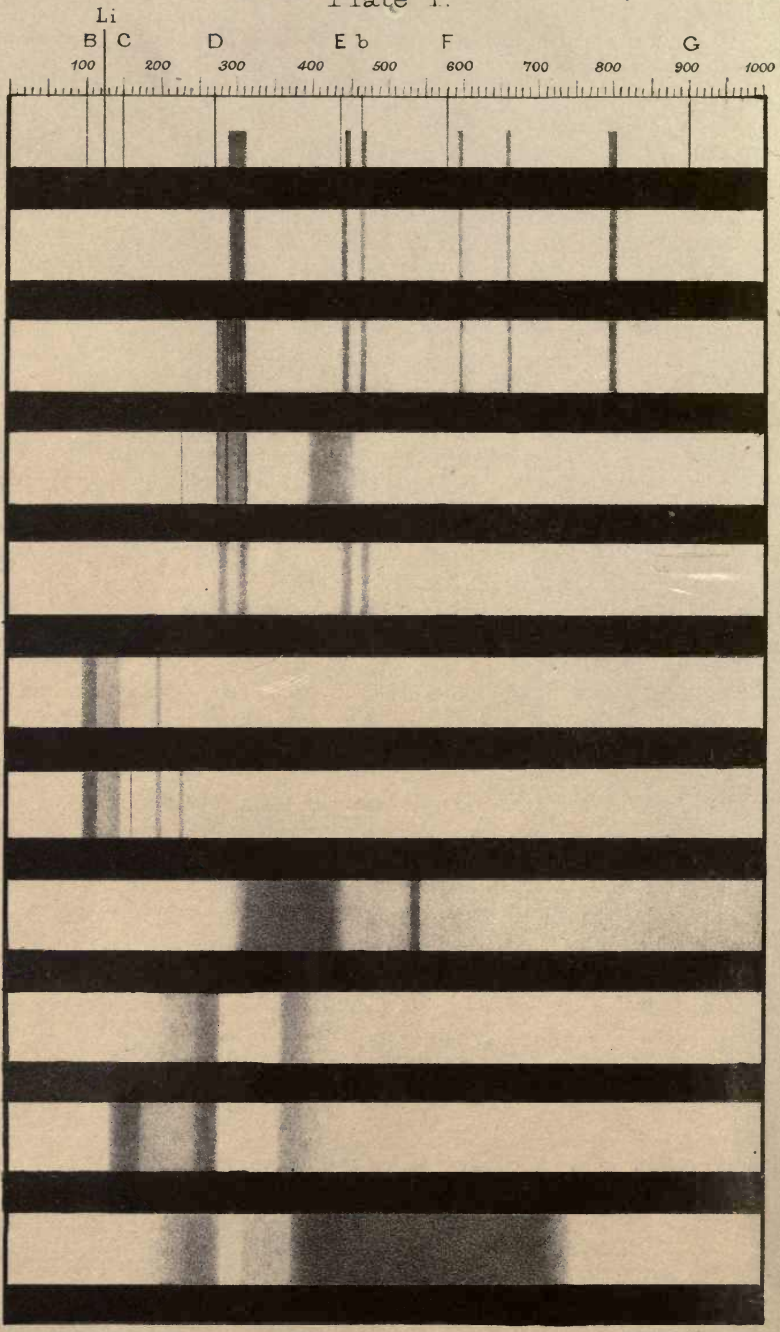
9. Indium. Two lines; one blue, the other violet.

10. SIRIUS. The continuous spectrum of a self-luminous body, with absorption lines as in the solar spectrum, but differing in some important particulars, especially the altered position of the F line, which has led to the discovery of the motion of the star.

11. NEBULÆ. A spectrum of incandescent gas, the highest blue line coinciding with F; that of hydrogen (Fig. 12), the lowest, with one of the lines of nitrogen (Fig. 13).

12. HYDROGEN. 13. NITROGEN. 14. COAL GAS. Bright line spectra, obtained by passing an electric spark through an attenuated atmosphere of the respective gases.

Plate 1.



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LONDON.

PLATE I.

1. NITRATE DIDYMIUM SOLUTION (*pale pink, almost colourless*).

2. OXALATE DIDYMIUM, POWDER (*white*), VIEWED BY REFLECTED LIGHT.*

3. DIDYMIUM GLASS (*pale violet, almost colourless*).†

4. OXIDE DIDYMIUM, BLOWPIPE BEAD IN BORAX (*colourless*).

The absorption-bands of these substances are remarkable for their extreme sharpness, which in nitrate of didymium is so perfect that it can be used as a scale to determine the position of lines and bands in the spectrum. In oxalate of didymium the lower band is wider than that of the nitrate, and with a good set of prisms is resolved into several dark lines. In didymium glass the lower band appears double, its constituents being connected by a very faint band. Between C and D a faint hair-like line is just visible, under favourable circumstances, with very perfect instruments: this line is more plainly seen in PARISITE (Plate III., Fig. 27). The place of the second and third bands is occupied by a faint general absorption; the three higher bands are wanting. In the oxide didymium the second and third bands are just visible; the first double, as in the preceding, but fainter. The intensity of the bands in didymium salts is remarkable when their almost colourless appearance is taken into consideration. The absorption-bands of didymium were described by Dr. J. H. Gladstone, in 1858.

5. CHLORIDE COBALT SOLUTION IN ALCOHOL (*bluish-purple*).

6. ,, ,, ,, IN CHLORIDE CALCIUM (*azure-blue*).

These two spectra closely resemble each other, and differ widely from the others of cobalt occupying the remainder of the page. Two bands, those nearest to the red end, are common to both. In No. 6 a third band is seen, and a fine hair-like line ‡ is to be detected with a very good instrument. The lowest band consists of two, that on the red side being darker than the other: the upper edge of this double band is coincident with the C line.

7. CHLORIDE COBALT, CRYSTAL (*crimson*). Differs entirely from either of the solutions of the same salt.

* Unless otherwise stated, transmitted light has been employed in viewing the spectra.

† From specimen made for Mr. Browning.

‡ This and also the line in No. 3 are too strong in the plate.

8. Oxide Cobalt, Blowpipe Bead in Borax (*blue*). (For further observations on cobalt blowpipe beads see paper by Charles Horner, "Chemical News," vol. xxvii., p. 241).

9. Cobalt Glass (*blue*).

These spectra are identical, the additional lower band being visible in the borax bead when more strongly coloured than the one figured. When a deeper glass is used only a narrow red band is transmitted, and the remainder of the spectrum cut off to the blue, according to the intensity of tint.

10. Cyanide Cobalt Solution (*purple-blue*). Differs from Nos. 8 and 9, notwithstanding its somewhat similar colour, but not otherwise remarkable.

Plate 2.

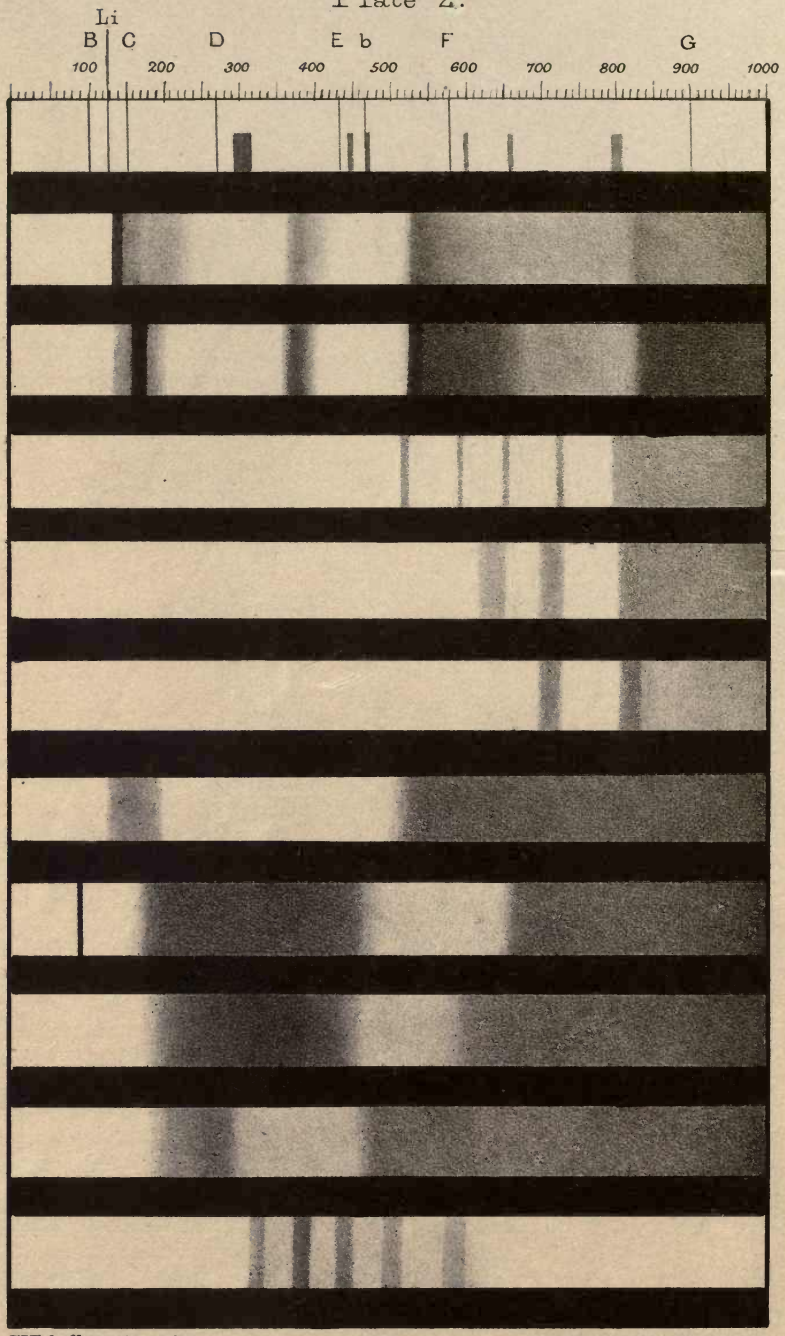

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PLATE II.

11. Oxide Uranium, Blowpipe Bead (*green*).

12. Sulphate Uranium, Solution (*greenish-yellow*).

The spectra resemble each other in their absorptions, the lower band excepted. In No. 12 this band is solid black throughout, unless a thin layer of the solution is viewed when the dark centre with a hazy band on either side becomes evident.

13. Uranite (Native Phosphate Uranium) Fragment Mounted in Balsam (*green*). Four narrow bands; general absorption in the violet corresponding with Nos. 14 and 15, and nearly with Nos. 11 and 12.

14. Chloride Uranium, Solution (*greenish-yellow*).

15. Acetate Uranium, Solution (*yellow*).

One band and the general absorption common to both. The upper band in No. 15 might probably, under favourable circumstances, be also seen in No. 14, but, from its position in the dark part of the spectrum, is difficult to determine; the lower band in No. 14 is peculiar to it.

16. Borate Uranium, Blowpipe Bead (*bottle-green*). Resembles No. 11 or No. 12, badly defined.

17. Oxalate Chromium and Soda, Solution (*blackish-purple*). Remarkable for the sharp narrow band in the red below B.

18. Sulphate Chromium, Solution (*dull reddish-purple*).

19. Nitro-Phenic Acid (*brown*).

20. Permanganate Potass, Solution (*crimson*). A very characteristic spectrum, of five bands, differing considerably from other red fluids, as Nos. 31, 39, 40, &c.

PLATE III.

21. Oxide of Copper, Blowpipe Bead Viewed by Reflected Light (*red*).

22. „ „ „ „ „ Transmitted Light (*bluish-green*).

In No. 21, as might be expected, the upper part of the spectrum is absorbed. In No. 22 a hazy band is seen in the upper part of the red, extending nearly to the D line.

23. Ruby Glass (*red*). This glass, which owes its colour to copper, has some resemblance to No. 22, but the band is higher.

24. Non-Actinic Glass (*orange*).

25. Ammonio-Sulphate Copper, Solution (*deep blue*).

Both of these media are made use of by photographers for widely different purposes: No 24 for excluding the actinic rays from the preparing-room, which it does most effectually, cutting off all the upper portion of the spectrum; this glass is much paler in tint than the ruby glass, No. 23, although its absorbing power is so great: No. 25, cutting off the whole of the red and yellow light, but permitting the chemical rays to pass freely, is used to illuminate objects by direct sunlight, for micro-photographic operations: without the ammonio-sulphate cell the object would be injured by the intense heat of the condensed solar rays.

26. Purple Garnet—India (*dull reddish-purple*).

27. Parisite (*brown*). A rare mineral, from the emerald mines of New Granada, consisting principally of carbonate of cerium, lanthanum, and didymium, the latter in excess. The spectrum is that of didymium modified by the optical properties of the crystal (compare Figs. 1, 2, 3, and 4). The very fine line between C and D is most distinct; the general absorption above F hides the three upper lines of the didymium spectrum.

28. Alkanet Root (*Anchusa tinctoria*), Alcoholic Tincture (*pink*).

29. „ „ „ „ „ with a little Carbonate of Soda (*violet*).

30. Alkanet Root, Excess of Carbonate of Soda (*purple-blue*). A good example of the action of an alkali upon a red vegetable colouring matter. See p. 23.

Plate 3.

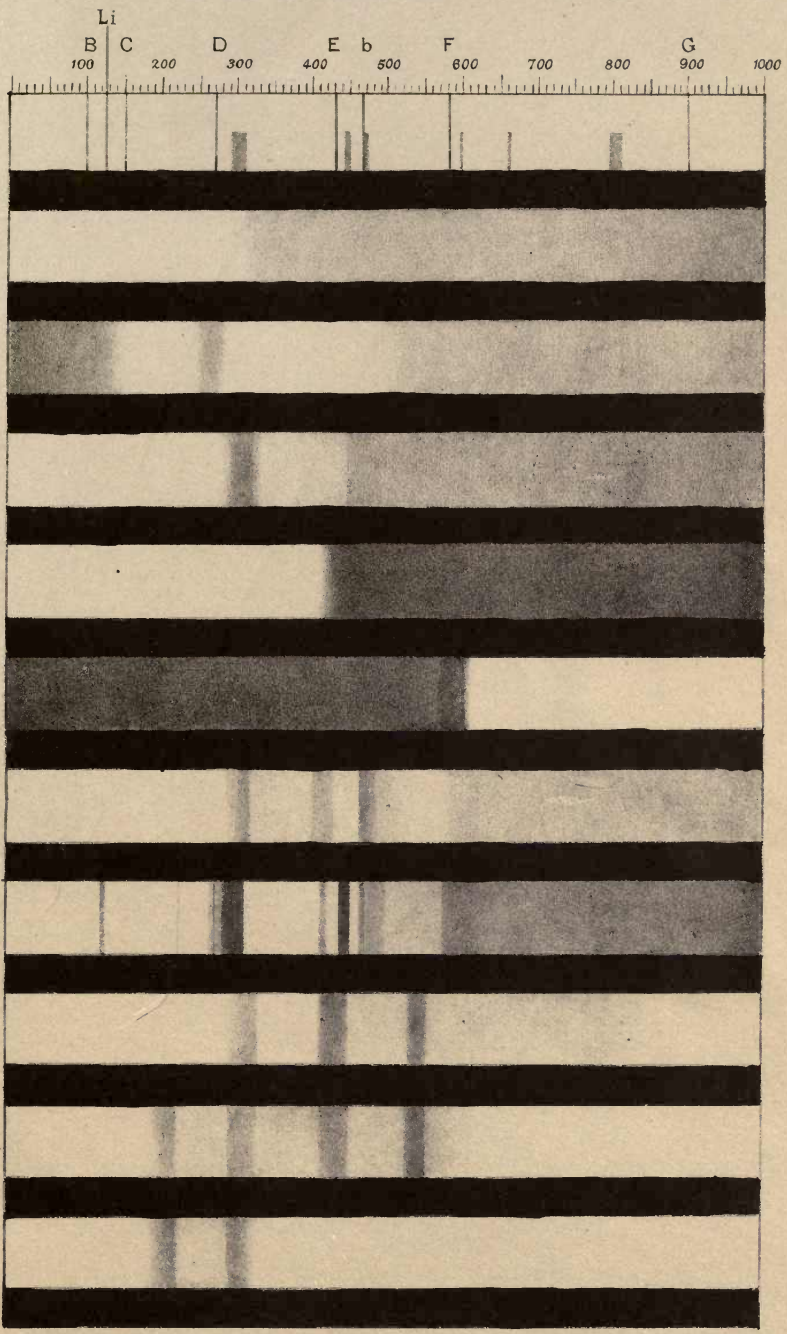

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Plate 4.

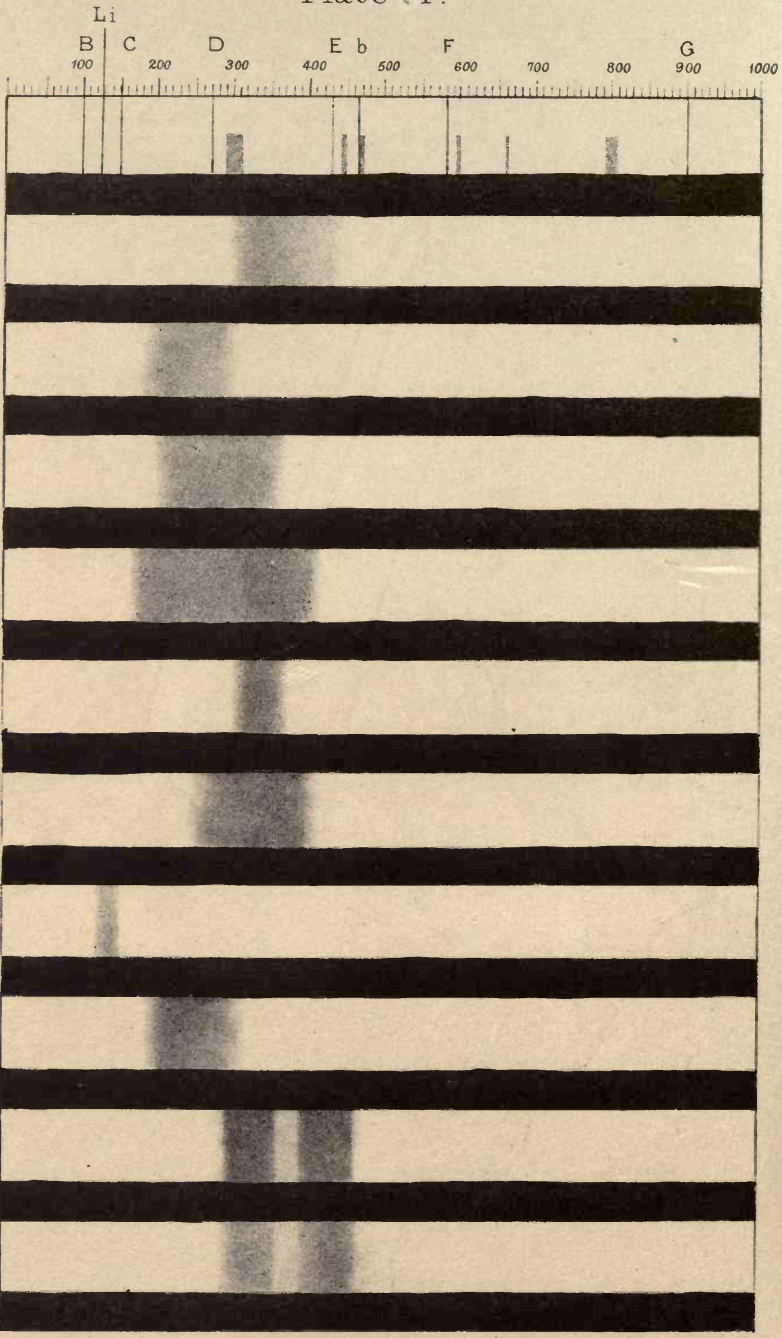

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PLATE IV.

31. MAGENTA.
32. GREEN.
33. BLUE, No. 1.
34. BLUE, No. 2.
35. VIOLET.
36. MAUVE.

} FILMS OF GELATINE COLOURED WITH ANILINE DYES.

A remarkably uniform series, and absorbing the complementary portion of the spectrum: the extent absorbed would probably be the same in each case provided the tints were of equal intensity. The width of the bands here, as in many other instances, is influenced by the quantity of colour; the extent of the absorption can be increased or diminished at pleasure.

37. IODINE GREEN, FROM A PIECE OF SILK VIEWED BY REFLECTED LIGHT. Remarkable for its resemblance to the characteristic band of chlorophyl.

38. SULPHATE INDIGO, SOLUTION (*blue*).

39. TURACINE, ALKALINE SOLUTION (*deep pink*). Obtained from the wing-feathers of the Cape lory (*Turacus albocristatus*). This spectrum was discovered by Professor Church, who found the pigment to contain copper.

40. CARMINE, GELATINE FILM (*red*). Closely resembles the preceding, but the bands are less definite: both have some slight resemblance to the spectrum of fresh blood (fig. 51).

PLATE V.

41. Chlorophyl from Foxglove Alcoholic Tincture (*green*).

42. ,, ,, Carnation ,, ,, (*green*).

43. ,, ,, ,, ,, ,, with Citric Acid (*yellowish-brown*).

The spectra of chlorophyl are among the most perplexing; the figures of authors differ considerably: the dark band in the red near C is common to all, and is seen even in the brown tincture obtained from the red leaves of the common beet—*Beta vulgaris* (fig. 50), and becomes more or less broad, according to the strength of the tincture: the other bands vary exceedingly. There are several colouring matters in the green of leaves. The best account is given by H. C. Sorby, F.R.S., in a paper "On the Various Tints of Autumn Foliage" ("Quarterly Journal of Science," vol. i., N. S., p. 64). The characteristic band in the red is the most stable, lasting long after the others have faded, as in the case of many of the tinctures of the Pharmacopœia, as *Hyoscyamus*, *Cannabis*, *Digitalis*, &c.

44. Rhodomenia palmata, from Frond Mounted in Balsam (*dull red*). The characteristic band of chlorophyl visible, and some others; figured by Mr. H. C. Sorby, "Monthly Microscopical Journal," vol. vi., p. 130.

45. Lobelia speciosa, Alcoholic Tincture of Petals (*blue*).

46. ,, ,, Alcoholic Tincture, with Carbonate of Soda (*green*). Already mentioned, p. 23.

47. Red Cineraria, Alcoholic Tincture (*crimson*). Much resembles No. 45, but the absorption bands are situated somewhat higher.

48. Tradescantia Virginica, Light transmitted through Petal (*red*) A three-banded spectrum, closely resembling No. 47. The red and blue varieties yield a precisely similar spectrum. This plant is well known to microscopists as exhibiting cyclosis in the beaded hairs surrounding the stamens.

49. Centaurea cyaneus, Infusion of Petals in Water (*blue*). The blue colouring matter is insoluble in alcohol; the absorption is totally different from that of *Lobelia*, consisting of a single ill-defined band.

50. Beet (*Beta vulgaris*), Alcoholic Tincture of Red Leaves (*brown*). See descriptions of Nos. 41 to 43.

Plate 5.

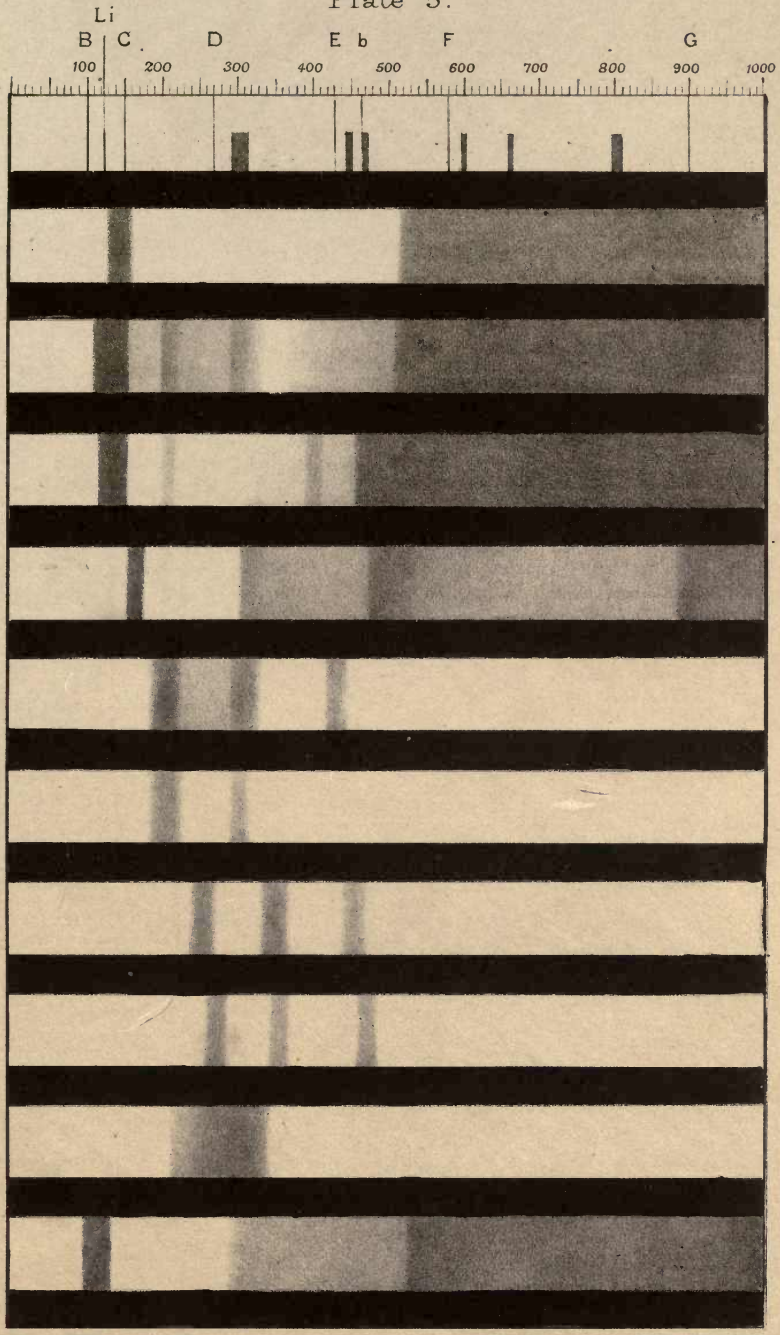

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Plate 6.

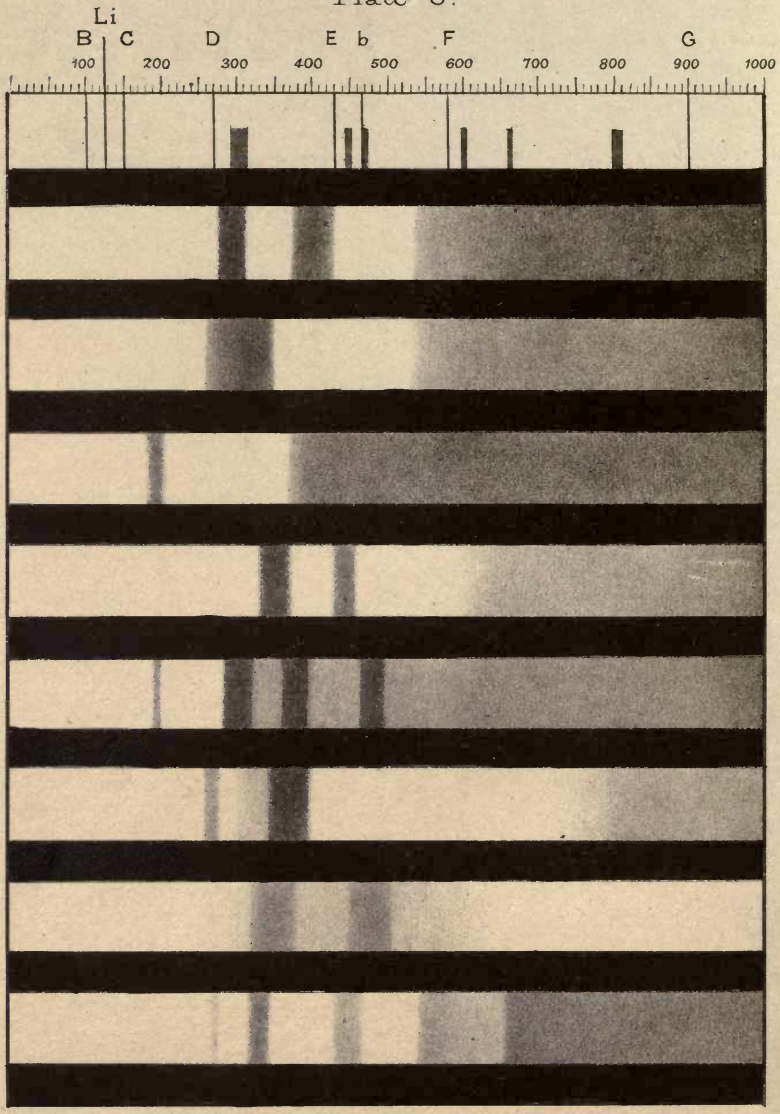

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PLATE VI.

51. Fresh Blood (Hæmoglobin).

52. Deoxidised Blood (Deoxidised Hæmoglobin).

53. Blood Treated with Citric Acid (Hæmatine).

54. Deoxidised Hæmatine.

55. Cruentine (Alkaline).

56. Sulphate Cruentine. Spectra described p. 24.

57. Madder Carmine, as prepared for water-colour painting by Messrs. Winsor and Newton, Dried Film Mounted in Balsam (*bright red*). At first sight resembles carmine or turacine, but the bands are higher in position.

58. Aphidirholeine (*orange*). A new colouring matter, obtained from *Aphides* by Mr. Sorby. Remarkable for the absorption-band covering the D line —an unexpected phenomenon in an orange-coloured fluid.

The following Prices are Nett for Cash; half-price allowed for returned Packages, if Carriage Paid.

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2. The above-named Instrument, Binocular, with rack and pinion adjustment to Drawer Tubes	42	0	0
2.*The above Instrument with Stephenson's Binocular arrangement, for use with high powers	47	0	0
3. Microscope, smaller size, with all the above adjustments, A and B Eye-pieces, Condenser for opaque objects, 1-inch 25° and ¼-inch 85°, with adjustment for correction to Objectives	16	10	0
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	£	s.	d.
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The Youth's Microscope, in case, complete, 8/6, 10/6, 15/,	1	1	0
Binocular arrangement fitted to any instrument, with adjustment to Eye-drawers and one extra Eye-piece	3	15	0
Ditto, with pair of Eye-pieces	4	10	0
Ditto, with Rack adjustments	5	10	0
Adapting Stephenson's Binocular arrangement to Student's stands, with two Eye-pieces, and sliding adjustment to draw tubes	7	0	0
To medium sized stands, with rack adjustment to the draw tubes	9	10	0
To best stands, with two draw tubes, and the bodies inclined so as to dissect with the Stage of the Microscope horizontal	15	10	0
Polarizing plane for this size, with fittings, extra ...	2	10	0
Browning's Improved Rotating Body Microscope ...	10	0	0

MICROSCOPE OBJECT GLASSES.

No. 1.

Power.	Angle.	Price.	Lieberkuhn.
3 in.	12 degrees.	£2 10 0	
2 in.	16 „	2 10 0	£0 15 0
1½ in.	20 „	2 10 0	0 15 0
1 in.	25 „	2 10 0	0 12 6
⅔ in.	35 „	3 0 0	0 12 6
*½ in.	85 „	4 10 0	
*¼ in.	100 „	4 10 0	
*¼ in.	120 „	5 10 0	
*⅛ in.	135 „	7 10 0	

The powers marked thus (*) are furnished with screw collar adjustment.

LOW ANGLE LENSES.

No. 2.

Power.	Angle.	Price.
3 in.	9 degrees	£1 5 0
2 in.	10 „	1 5 0
1 in.	15 „	1 5 0
½ in.	55 „	2 0 0
¼ in.	75 „	2 2 0

MICROSCOPIC APPARATUS.

	£	s.	d.
Extra Eye-pieces ... ... 12/6 and	0	15	0
Indicator for ditto, extra	0	5	0
Kellner's Achromatic Eye-piece ... ... £1 and	1	5	0
Stage Micrometer	0	5	0
Ditto, mounted in brass frame	0	7	6
Eye-piece Micrometer	0	5	0
Ditto, with brass fittings and screw adjustments ...	0	18	0
Erecting Eye-piece	1	0	0

	£	s.	d.
Camera Lucida ... ... 15/ and	1	0	0
Beale's ditto	0	7	6
Achromatic Condenser, with revolving Diaphragm and full set of stops	5	0	0
Achromatic Condenser	2	10	0
Webster's ditto	2	0	0
Ditto, with Rack Adjustment and graduated Diaphragm	4	0	0
Wenham's Parabola, for dark ground illumination, 21/ to	1	11	6
Spot Lenses ... ... 7/6 to	0	15	0
Stage Condensers	0	7	0
Stand ditto ... ... No. 1, 2, 3, 4, 9/6, 12/6, 17/6	1	0	0
"Silver" Side Reflectors, fitted to Stage	1	0	0
Lieberkuhn's ditto ... ... 10/ to	0	15	0
Parabolic ditto ... . 20/ and	1	10	0
Brooke's Double Nose Piece ... ... from 12/6 to	1	10	0
Polariscope, No. 1, 2, 3, 4, £1 5s., £1 10s., £2 2s., and	2	10	0
Darker's Selenite Stage, and set of Selenites	2	0	0
Selenite Stage Plates	0	2	0
Rotating Object Holder	0	8	0
Lever Compressorium	0	18	6
Lister's Dark Wells ... ... from 5/ to	0	12	6
Live Cages ... ... from 3/6 to	0	7	6
Stage Forceps ... ... from 4/6 to	0	7	6
Hand Forceps ... ... from	0	1	0
Maltwood's Finder	0	5	0
Glass Troughs ... ... from	0	1	6
Zoophyte ditto	0	6	0
Microscope Lamps ... ... from 8/6 to	1	11	6
Fiddian's ditto, portable, in case, with metallic chimney	1	11	6
Reed's Diatom Prisms (mounted) ... ... 15/, 21/, and	1	11	6

APPARATUS FOR MOUNTING.

	£	s.	d.
Machine for cutting sections of wood ... ... from	0	15	6
Dissecting Knives ... ... from	0	1	6
Valentine's ditto	1	1	0
Chisels... ... ... from	0	2	6
Spring Scissors	0	7	6
Curved Scissors	0	4	6
Fine ditto	0	2	0
Elbow ditto	0	3	6
Steel Forcep	0	1	6
Ditto curved	0	2	0
Dissecting Needles, set of three	0	2	0
Brass Table and Spirit-Lamp for mounting objects 7/6 and	0	10	6
Rotating Table for making Cells ... ... from	0	6	6
Air Pumps for Mounting	1	0	0
Plate Glass Slides, 3-inch by 1 inch ... per doz.	0	0	4
Ditto, ditto, with ground edges ... ... ,,	0	0	8
Ditto, ditto, ditto, and excavated Cells ... ... ,,	0	2	6
Ditto, ditto, ditto, round glass ditto ... ... ,,	0	3	6
Ditto, ditto, ditto, square ditto ... ... ,,	0	5	0
Thin covering glass, circles various sizes... ... per oz.	0	5	0
Ditto, ditto, squares ditto	0	3	6
Ring Cells in Metal, Ivory, and Glass ... from per doz.	0	0	6
Adhesive Labels for covering objects ... per 100	0	1	6
Canada Balsam ... ... from per bottle	0	1	0
Asphaltum ... ... ,,	0	1	0
Gold Size ... ... ,,	0	1	0
Dean's Gelatine Medium ... ... ,,	0	1	6
Glycerine, pure ... ... ,,	0	1	0
Marine Glue ... ... 9d. and	0	1	0
Sets of Apparatus for Mounting, in case complete, £1 15s., £2 10s., £5, £8, and	10	0	0

SPECTRUM APPARATUS FOR THE MICROSCOPE.

	£	s.	d.
The Sorby-Browning Micro-Spectroscope, with Rack motion to Eye-piece	6	0	0
Case for ditto, with Racks for Cells and Tubes	0	15	0
Sorby's Tubes... ... ... per doz.	0	2	6
Sorby's Wedge Cells...	0	6	0
Specimens in Sealed Tubes, for showing the bands, each	0	1	6
The Amateur's Micro-Spectroscope, with achromatic lens and reflecting prism, to show two spectra at the same time, for the purpose of comparison	2	12	6
Mahogany Cases for the above	0	5	0

HAND MAGNIFIERS FOR DISSECTING.

Pocket Magnifier, one Lens, Horn Mounting	0	1	0
Ditto, ditto, Tortoiseshell ditto	0	3	6
Ditto, two Lenses, Horn ditto	0	2	6
Ditto, ditto, Tortoiseshell ditto	0	4	6
Ditto, three Lenses, Horn ditto	0	3	6
Ditto, ditto, Tortoiseshell and Silver ditto	0	5	6
Ditto, four Lenses, ditto, two Diaphragms, &c., from 12/6 to	1	5	0
Stanhope Lens	0	2	6
Coddington ditto ... ... from	0	3	6

MICROSCOPIC OBJECT CABINETS.

	£	s.	d.
Cloth Boxes, with Rack for ½ doz. objects	0	0	6
Ditto ditto 1 ditto	0	0	9
Ditto ditto 2 ditto	0	1	0
Ditto ditto 3 ditto	0	1	6
Polished Mahogany ditto 2 ditto	0	3	6
Ditto ditto 4 ditto	0	6	0
Ditto ditto 6 ditto	0	8	0
Upright Polished Pine Cabinet, with drawers to hold 150 objects	1	10	0
Ditto, ditto, ditto, to hold 250 ditto	2	0	0
Ditto, ditto, ditto ,, 500 ditto	3	0	0
Superior Upright Solid Mahogany Cabinet, with drawers to hold 150 objects	2	0	0
Ditto, ditto, ditto, to hold 250 objects	2	15	0
Ditto, ditto, ditto ,, 500 ditto	3	10	0
Ditto, ditto, ditto ,, 750 ditto	4	10	0
Ditto, ditto, ditto ,. 1000 ditto	5	5	0
Best ditto, ditto ditto	7	15	0

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A large assortment of Microscopic Specimens by the best mounters, always in stock ... ... from per doz.	0	12	0
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Ditto ditto ditto 12 ditto ...	0	12	0
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	£	s.	d.
Half-hours with the Microscope (Lankester)	0	2	6
Objects for the Microscope (Lane Clarke)...	0	3	6
Ditto ditto (Hon. Mrs. Ward)	0	3	6
Marvels of Pond Life (Slack)	0	5	0
The History of the Microscope (Hogg)	0	7	6
The Microscope and its Revelations (Carpenter)... ...	0	12	6
How to Work with the Microscope (Beale)	1	1	0
Practical Treatise on the Use of the Microscope (Quekett's)	1	2	0
"Infusoria" (Pritchard)	1	16	0
Micrographic Dictionary (Griffith and Henfrey)	2	5	0

The following Prices are Nett for Cash; half-price allowed for returned Packages, if Carriage paid.

JOHN BROWNING'S PRICED LIST OF SPECTROSCOPES.

THE MINIATURE SPECTROSCOPE.

Dimensions $\frac{7}{10}$ diameter, 3 inches long.

This instrument will show many of Fraünhofer's lines, the bright lines of the metals and gases, and the absorption bands in coloured gases, crystals, or liquids.

	£	s.	d.
Price, with five prisms	1	2	0
Ditto, with adjustable slit. (Fig. 1)	1	13	0
Morocco case, extra	0	2	0
Ditto, with Achromatic Lenses, &c., &c., in Morocco Case	2	6	0
New form Direct-Vision Spectroscope, with five Prisms, fitted in Mahogany Case	5	15	6

This Spectroscope is a most powerful and portable Direct-Vision Instrument, easily separating the D lines in the solar Spectrum.

Large size, and extra power Eye-piece, complete in Mahogany case	6	18	6
Micrometer Measuring Apparatus for Direct-Vision Spectroscope, extra	3	5	0
Extra power Eye-pieces for the above ... ... each	0	12	6

CHEMICAL SPECTROSCOPES.

The Student's Spectroscope, in Stained Cabinet (Fig. 3)	6	10	0
The Model Spectroscope (Fig. 4), with two Prisms, in Polished Mahogany Cabinet	15	0	0
The Model Spectroscope, with four Prisms, in superior Cabinet, with Fittings and two Eye-Pieces	27	10	0
Browning's Automatic Action, extra	6	10	0
The Large Model Spectroscope for the use of Physicists, made on the plan of the Gassiot Spectroscope (Fig. 5)	38	10	0
Dividing ditto on Silver, extra	2	0	0
The above Instrument, the circle divided on Silver to 10 seconds, with five Prisms, four Eye-pieces, and parallel wire Micrometer, for measuring the position of lines to $\frac{1}{10000}$ of an inch, the whole in Mahogany Case	55	10	0
Browning's Automatic Action to either of the above Instruments, extra	12	10	0

Larger Spectroscopes to Order.

BROWNING'S NEW AUTOMATIC SPECTROSCOPE.

The Automatic Spectroscope, with six Prisms and six Eye-pieces, in Case complete (Fig. 6)	50	0	0
Ditto, ditto, same size as large Model Spectroscope ...	90	0	0
Browning's Universal Automatic Spectroscope, with which any dispersive power may be used at pleasure, without deranging the adjustments of the instrument by means of the reversion of the ray. With this instrument a dispersive power, ranging from two prisms to twelve, can be employed	60	0	0

TELE-SPECTROSCOPES FOR SOLAR OBSERVATIONS.

	£	s.	d.
Solar Spectroscope, as made for J. Norman Lockyer, Esq., F.R.S., for his researches on the Chromosphere ...	45	0	0
Ditto, Direct Vision, with less dispersive power ...	14	0	0
Browning's Solar Spectroscope, with Rutherford's Prism, adapted for any Telescope from 4 inches to 12 inches in aperture	35	0	0

PRISMS.

Prisms of extra dense flint, of very superior quality, ¾ in., of 45 or 60 degrees, and accurate plane surfaces ...	0	15	0
Ditto, 1 in., 20s.; 1¼ in., 30s.; 1½ in., 60s.; 2½ in., 90s.; 2¾ in.	6	0	0
Ditto, 3 in., £15; 4 in. by 3 in.	30	0	0
Bisulphide of Carbon Prisms, large size	0	15	0
Bisulphide of Carbon Prisms, with Parallel Glass Sides, Browning's improved method of mounting in Metal Frames ... ... each	1	15	0

PRISMS OF OTHER ANGLES TO ORDER.

STAR SPECTROSCOPES.

The Amateur's Star Spectroscope, in Mahogany Case (Fig. 8) .., ...	4	0	0
Star Spectroscope, with one Prism, packed in Polished Mahogany Case	8	8	0
Star Spectroscope, with two Prisms, reflecting Prism, to show two spectra at once, and Micrometer Measuring Apparatus for mapping spectra, packed in Polished Mahogany Case	14	0	0
Star Spectroscope of the best construction, with adjustable reflecting Prism and Mirror, with finest object glass Micrometric Apparatus for measuring the lines of the spectrum to $\frac{1}{10000}$ of an inch, extra Eye-piece, and Ivory Tube to Reader of Vernier, as made for W. Huggins, Esq., F.R.S., packed in polished Mahogany Case (Fig. 7), with insulated Spark Apparatus attached to Mirror, for obtaining the spectra of the metals for comparison	21	0	0

INDUCTION COILS.

Induction Coil, to give half-an-inch spark in dry air ...	3	10	0

Well adapted for working with Geissler's tubes, and obtaining a spectra of various gases by means of the Spectroscope.

Ditto, to give a 1-inch spark	7	0	0
Ditto, to give a 1½-inch spark	10	0	0
Ditto, to give a 2½-inch spark	13	10	0
Ditto, to give a 4½-inch spark, with Browning's Improved Break	18	10	0
Ditto, to give a 6-inch spark	25	10	0

Coils above 1-inch spark are adapted for deflagrating metals so as to obtain their spectra by the aid of the Spectroscope.

SPECTRUM APPARATUS FOR THE MICROSCOPE.

	£	s.	d.
The Sorby-Browning Micro-Spectroscope	5	15	0
Ditto ditto with rack motion to eye-piece. (Fig. 12)	6	0	0
Browning's bright line Micrometer for measuring position of bight lines in spectra. (Fig. 13)	2	5	0
Putting rack motion to a finished £5 5s. instrument ...	0	15	0
Case for ditto, with Racks for Cells and Tubes	0	15	0
Sorby's Tubes ... ... per doz.	0	2	6
Sorby's Wedge Cells ... ... per doz.	0	6	0
Specimens in Sealed Tubes for showing the bands, each	0	1	6
The Amateur's Micro-Spectroscope, with achromatic lens and reflecting prism, to show two spectra at the same time, for the purpose of comparison. (Fig. 14) ...	2	15	0
Mahogany Case for the above	0	5	0

SUNDRY SPECTROSCOPIC APPARATUS.

Spectrograph, for mapping out spectra	10	0	0
Ditto ditto larger	15	0	0
This instrument was suggested by Mr. BECKLEY, of Kew Observatory.			
Hollow Cells, with one side formed of a prism, for holding solutions for examining absorption bands	1	1	0
Large ditto, for projecting spectra on screen	1	11	6
Extra power Eye-pieces ... ... each 12s. 6d. to	1	0	0
Bunsen's Burners ... ... 3s. 6d. to	0	5	0
Adjusting Clip, on stand, to hold platinum wires ...	0	3	6
Browning's Improved Spectroscope Lamp, containing burner and clip on a single stand, complete. (Fig. 15)	0	12	6
Leyden Jars ... ... from 3s. 6d. to	2	2	0
Insulated Spark Apparatus, on Brass Stand, with two Discharges for obtaining the spectra of metals and gases	1	18	6
Browning's New Spark Condenser. (Fig. 16)	3	0	0
Ditto, with shifting connections	3	15	0
A convenient substitute for the Spark Apparatus, and Leyden Jars, for burning metals for spectrum analysis.			
Becquerel's apparatus for obtaining the spectrum of a substance in solution ... ... extra	0	15	0
Set of 13 chemically pure Metals, in Mahogany Cabinet, for spectrum experiments	0	18	6
Vacuum Tubes, prepared for showing the beautiful Spectra of various Gases—Nitrogen, Hydrogen, Oxygen, Carbonic Acid, Ammonia, Sulphuric Acid, Olephiants, Chlorine, Bromine, Iodine, Coal Gas, Æther Vapour, Turpentine Vapour, and Petroleum Oil Vapour, each ... ... 5s. 6d., 7s. 6d.	0	8	6
Set of Salts best adapted for showing Chemical Spectra, stoppered bottles, in case	0	7	6

METALLIC THALLIUM AND OTHER CHEMICALS TO ORDER.

Platinum Wire ... ... per foot	0	1	0

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PROFESSOR ROSCOE'S LECTURES ON SPECTRUM ANALYSIS, largely illustrated; six Lectures on Spectrum Analysis and its applications, delivered before the Society of Apothecaries.

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SPECTRUM ANALYSIS in its application to Terrestrial Substances and the Physical Constitution of the Heavenly Bodies, familiarly explained by Dr. H. SCHELLEN, Director der Realschule I. O. Cologne. Translated from the Second German Edition by JANE and CAROLINE LASSELL; edited, with Notes, by WILLIAM HUGGINS, LL.D., D.C.L., F.R.S.

	£	s.	d.
Photographed Chart of Solar Spectrum drawn and engraved by Fraünhofer, presented to John Browning by Lord Lindsay	0	2	6
Ditto of the Spectra of the Alkaline Earth, 36 by 30 inches	0	7	0
Ditto of the Metals	0	7	0
Ditto of the Stars and Nebula	0	7	0
Ångström's Normal Spectrum, on which the wave lengths of the Fraünhofer lines, and the lines of the metals are marked in 10,000,000 of a millimetre, in Six Plates, with description	0	10	6

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Illustrated Catalogue of Spectroscopes, with coloured Chart of Spectra, and practical instructions for the use of the Chemical Spectroscope, the Tele-Spectroscope, the Micro-Spectroscope, and Screen Spectrum Apparatus, Price One Shilling and Sixpence. By Post Eighteen Stamps.

JOHN BROWNING,

OPTICAL AND PHYSICAL INSTRUMENT MAKER

To Her Majesty's Government, The Royal Society, The Royal Observatories of Greenwich and Edinburgh, and the Observatories of Kew, Cambridge, Durham, Utrecht, Melbourne, &c., &c.

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LONDON.

DESCRIPTION OF THE NEW AUTOMATIC ELECTRIC LAMP.

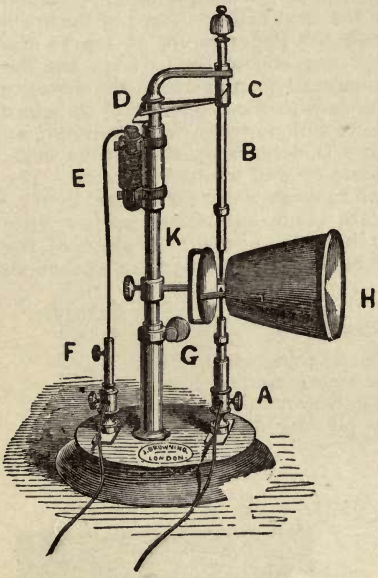


FIG. 1.

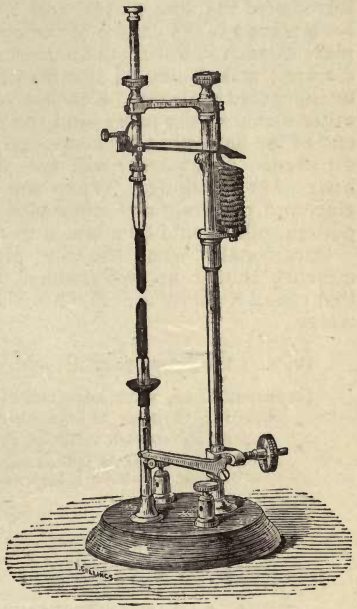


FIG. 2.

IN the above engraving the carbon points are carried by the holders, A B, which are provided with rings like a porte-crayon, to clamp the points when in position. C D is a soft iron feeder; the end, C, of this feeder is so arranged that a very slight pressure on the feeder clamps the rod, B, and prevents it from descending. E is a rod of soft iron, in the form of a horse-shoe: when the electricity passes through the wire wound upon this horse-shoe, the iron becomes a magnet, and attracts the feeder. F and G are clamping screws to clamp the sliding rods in any required position. H is a silvered parabolic reflector, for throwing the light of the Lamp to a great distance.

To Set the Lamp in Action.

Release the clamps, F G, place two pieces of fine hard carbon in the holders; the carbons should be well pointed; wipe the rod, B, with a leather, so that it may slide freely; then adjust the large central rod so that the extreme point of the upper carbon exactly rests upon the lower carbon. Attach the wire from the last plate of zinc in the battery to the lower carbon holder, and the wire from the plate of platinum at the opposite end of the battery to the upper carbon holder. If the light should not burn steadily, alter the position of the magnet by means of a small set screw between the ends; this screw is not shown in the drawing. The magnet must not be put close to the feeder; the best distance to place the magnet from the feeder is generally about half an inch, but this will vary with the power of the battery employed. When correctly adjusted, there should be no perceptible movement of the feeder.

Instructions for Charging the Battery.

Fill the porous cells with nitric acid—that is, commercial aquafortis—and insert the platinum foil or carbon plate. In a strong stoneware vessel, mix one part of oil of vitriol—that is, commercial sulphuric acid—with seven parts of water. Fill the outer cells with this mixture, having first introduced the zinc plates and porous cells. After the porous cells have been placed in the centre of the zinc plates, connect the platinum or carbon plate in each cell with the zinc plate in the next cell by means of the brass clamps; attach one of the clamps with the finger-screw at top to the unconnected platinum or carbon plate at one end of the battery, and the other clamp of the same kind to the unconnected zinc plate at the opposite end of the battery; then connect these ends with the copper wires as before directed. The battery will not attain its full power in less than half an hour after charging. When the battery is done with, the porous cells, zinc and platinum or carbon plates should be well washed in water. The porous cells should be allowed to remain in fresh water for several hours.

Occasionally, when the zinc plates are taken out of the acid, a little mercury thould be well rubbed over them, by means of a piece of rag tied round a small stick. This should be done before they are washed in water.

	£	s.	d.
Price of the Lamp (Fig. 1), with Reflector	2	5	0
Improved ditto, with adjustment for keeping the points of the burning carbons at one height, or separating them to any required distance, without Parabolic Reflector (Fig. 2) ..	2	15	0
This adjustment is indispensable for projecting the Spectra of Burning Metals on a Screen.			
Reflectors, extra	0	6	6

BROWNING'S NEW LARGE AUTOMATIC ELECTRIC LAMP.

(Fig. 3.)

Price, £9 9s.

Parabolic Reflector, £2 2s.

In this Lamp both carbons are moved by the electricity of the battery employed (without the aid of clockwork); the light remains uniform in height and more steady in action than by any of the expensive regulators previously introduced. From 25 to 50 quart Grove's cells, or the same number of 2 quart Bunsen's, should be used with this lamp.

For a full description of these Lamps and their performance, see Rossiter's Physics. *or Dr. Atkinson's translation of* Ganot's Physics. *For other notices, see* Scientific Opinion, *Dec. 30th,* 1868; British Journal of Photography, *Oct. 30th,* 1868; *or the* Mechanic's Magazine, *Nov. 13th,* 1868.

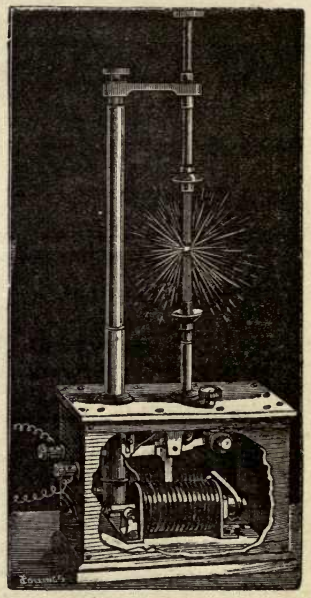
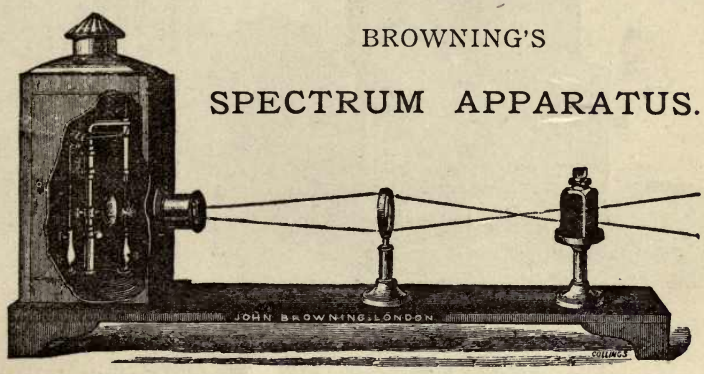


Fig. 3.

	£	s.	d.
Carbon Rods for Burning in Small Lamp, per foot	0	1	0
Ditto, per dozen feet	0	10	0
Large Rods for Burning in the Large Lamp, per foot	0	1	6
Ditto, per dozen feet	0	15	0
Carbon Cups for holding Metals to obtain their Spectra, per dozen .. .. small, 10s.; large	0	12	6

PRICES OF BATTERIES.

	£	s.	d.
Grove's Cells .. .. pints, 11s.; quarts	0	14	0
Bunsen's .. .. .. pints, 5s. 6d.; quarts, 6s. 6d.; 2 quarts	0	9	0
Varnished Oak Trays .. .. for 6 cells, 6s.; for 10 cells	0	10	6
Insulated Copper Wire, per yard .. .. 2d. to	0	1	3



BROWNING'S

SPECTRUM APPARATUS.

FIG. 4.

JOHN BROWNING has great pleasure in introducing to the notice of Lecturers and others a complete set of apparatus for projecting the spectra of metals, or the absorption bands of liquids, on a screen. The apparatus comprises an Automatic Electric Lamp and Lantern, with slit, battery, and tray, mounted focussing lens, bisulphide of carbon prism and stand, platform for the whole, and packing or travelling case.

	£	s.	d.
Price with 12 quart Bunsen's Cells (Fig. 4)	10	0	0
" " 20 " " "	12	10	0
Nozzle with lenses and 3¼ inch condensers, for showing diagrams or views on screen, extra	2	15	0
Very complete and powerful set of Spectrum Apparatus, consisting of Browning's New Large Automatic Electric Lamp, *without clockwork*, Lantern for ditto, with slit arrangement; battery of 30 quart Grove's cells in tray; large focussing lens, mounted on stand; two bisulphide of carbon prisms on stands; platform for the lamp apparatus, and two packing or travelling cases..	45	0	0
Nozzle with 4½ condensers, extra..	45	10	0
Mahogany box, fitted with metals for burning in the electric arc, carbon crucibles, and pliers	2	10	0

Illustrated Catalogue and Description of Spectroscopes sent for 18 *stamps.*

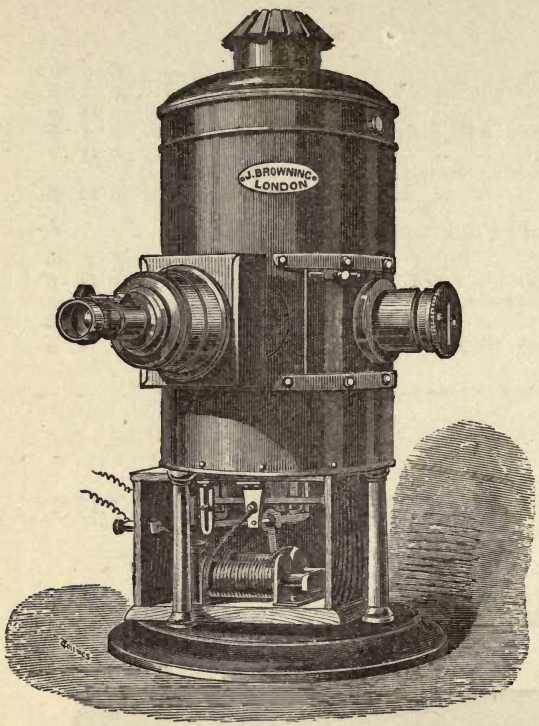


FIG. 5.

	£	s.	d.
Electric Lantern for Large Lamp, mahogany body, tin inner casing, with brass rack-work, nozzle, and 3½ inch condensers	7	10	0
Improved Lantern, the body of brass, bronzed, with two nozzles, specially arranged for exhibiting spectra or diagrams on the same screen without shifting the lantern or re-arranging the apparatus, with 3½ inch condensers (Fig. 5)	11	10	0
Ditto, ditto, larger size, and 4¼ inch condensers	16	10	0

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MICROSCOPICAL AND NATURAL HISTORY CLUB.

PRESIDENT:
HENRY DEANE, F.L.S., F.M.S., F.R.M.S.

THIS Club was established in accordance with a resolution passed at a Public Meeting; the objects which it is intended to fulfil being:—

FIRST.—To enable Microscopists and lovers of Natural History, residing in the District, to meet and interchange communications and specimens at stated intervals; to exhibit objects likely to prove interesting to the Members and Visitors; to promote the acquisition of skill in the use of the Microscope, and an acquaintance with the manifold beauties of nature, which, invisible by unaided vision, are so marvellously revealed by our modern instruments.

SECOND.—By Lectures and Papers, to afford instruction to the younger Members in the use of the Microscope, and preparation of objects, and to develope a taste for the study of Zoology and Botany.

THIRD.—By occasional Excursions into the country around, to investigate the natural productions of the District, and procure fresh materials for observation, which eventually may lead to the formation of a Cabinet and Herbarium, illustrative of the indigenous Fauna and Flora of East Surrey.

The Annual Subscription is Ten Shillings.

The Meetings are held on the Third Tuesday in each month, at 8 o'clock p.m., at Glo'ster Hall, 6, Glo'ster Place, Brixton.

One Visitor may be introduced by each Member.

HON. SECRETARY:
FREDK. HOVENDEN, 63, Angell Road, Brixton, S.W.

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