











# ATLAS OF ABSORPTION SPECTRA

BY

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## INTRODUCTION.

By R. W. Wood.

In spite of the very large amount of work which has been done on absorption spectra, there exists practically no collection of photographed spectra from which one can pick out the media most suitable for any particular line of investigation. The greater part of the published records are drawings made from visual observations, and give no information regarding the optical properties of the media in the ultra-violet. It seems desirable therefore to compile a set of photographic records which are free from the errors liable to enter into observations made by visual methods, and to arrange them in such a way that the medium or media necessary to secure a desired result could be readily found from a mere inspection of the plates.

A great deal of experimental work was necessary before satisfactory photographic records were obtained. The details of the spectrograph and the refinements of the method have been worked out very skilfully by Dr. Uhler, who has done practically all of the experimental work. It was our original plan to include the colored salts of metals, and to examine a large number of colorless substances for peculiarities in the ultra-violet. The solutions of the inorganic compounds could not, however, be investigated in precisely the same manner, owing to their less powerful absorption. Much thicker absorbing wedges were required, and these gave trouble, even when compensated, as a result of dispersion. It was therefore decided to limit the present work chiefly to a study of the aniline dyes, which are used to a much greater extent than the metallic salts, in the preparation of absorbing screens. The absorption spectra of a number of metallic salts, however, have been photographed, as it is believed that many of them will be useful in the preparation of ray filters; some of them are far more transparent in the ultra-violet than the aniline dyes. Even such substances as the salts of erbium, neodymium, and praseodymium are useful in special cases where it is desired to suppress one or more isolated spectral lines. For example, a solution of neodymium has a very narrow and intense band coincident with the D lines, and has therefore the property of cutting out the sodium radiation from a given source, transmitting at the same time nearly the whole of the remainder of the spectrum. The same salt can be used to advantage when working with the new cadmium and zinc arc lamps in quartz tubes,

made by Heraeus. The fact that the absorption of each substance in the ultra-violet is recorded, makes the plates of especial value to any engaged in the preparation of screens for spectroscopic or photographic purposes.

For the removal or transmission of one or more isolated lines some other arrangement is often more useful than an absorbing screen. A spectroscope with a slit placed in the focus of the observing telescope (monochromatic illuminator) is frequently all that is necessary. But if more light is required, the following device may be used. A block of quartz from 2 to 4 cm. in thickness, cut perpendicular to the optic axis, is mounted between two Nicol prisms. The transmitted spectrum is crossed by black bands, which result from the rotatory power of the quartz. By adjusting the nicols and varying the thickness of the quartz it is often possible to get rid of the spectrum lines which are not desired, and at the same time to utilize the whole area of the source, which can never be done with the spectroscope. In this way, with a quartz plate 45 mm. thick, the line 4809 of the zinc arc in quartz can be completely removed and the two lines 4721 and 4679 transmitted. This method is especially useful in the study of the fluorescence excited in various bodies by monochromatic light.

If it is necessary to separate radiations of very nearly the same wavelength, for example if we wish to work with the light of one of the two sodium lines, the following arrangement can be used: A quartz plate about 2 cm. in thickness, cut parallel to the axis, is mounted between crossed nicols, with its axis making an angle of  $45^\circ$  with the principal planes of the polarizing prisms. The source is placed behind a vertical slit 2 or 3 mm. in width, and the light, after traversing the polarizing system is brought to a focus by a lens. A number of concentric maxima and minima will be formed, the light of  $D_1$  and  $D_2$  being found in adjacent maxima. The wave-length which is not desired can be stopped by a screen of suitable dimensions placed at the focus of the lens. In this way it is possible to obtain a source of  $D_1$  or  $D_2$  radiation of sufficient intensity to show distinct fringes in a Michelson interferometer. By a curious coincidence this method occurred independently to the writer and to Professor Michelson on the same day. It has been found to give excellent satisfaction. The thickness of the quartz plates used in either of the above cases depends upon the closeness of the lines which it is desired to separate.

We are under great obligation to the Actiengesellschaft für Anilinfabrikation and to Meister, Lucius & Brüning, both of which firms presented the Johns Hopkins University with a large collection of aniline dyes.

# ATLAS OF ABSORPTION SPECTRA.

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## OBJECT OF THE PRESENT INVESTIGATION.

If we look over the literature of the subject of absorption of light we fail to find a collection of absorption spectra presented in such a manner as to enable the observer to select at a glance a substance which produces either general or selective absorption in any specified part of the visible or ultra-violet spectrum. The wave-lengths of the absorption bands and other characteristics of the absorption exhibited by innumerable natural and artificial compounds and mixtures, both inorganic and organic, may be found in a great many books, journals, memoirs, and dissertations. If all of these results were reproduced and catalogued in one volume they would not satisfactorily fulfil the requirements just mentioned, because the different experimenters have had various objects in view and hence they have worked in various and limited parts of the spectrum, have used different numerical dispersions, have employed optical systems of unlike dispersion curves, have not made it possible even to reduce their results to graphical form much less to a common basis of wave-lengths and normal dispersion, etc. The nearest approach to a work of the kind under consideration is made by the publications of J. Formánek, especially the two volumes entitled respectively "Die Qualitative Spektralanalyse anorganischer Körper" and "Spektralanalytischer Nachweis künstlicher organischer Farbstoffe;" Berlin, 1900. Formánek's investigations are very extensive and complete from the point of view explicitly stated in the preface to the last-named volume. It was his aim to develop a practical spectroscopic method of procedure by which any given organic coloring matter could be unambiguously identified. He says:

"Das Princip des hier beschriebenen neuen Verfahrens beruht auf der Kombination der spektralanalytischen Beobachtung und der chemischen Untersuchung; dieses Verfahren liefert nicht nur sichere Resultate, sondern sein Vortheil liegt auch darin, dass man mit Hilfe desselben alle einzelnen Farbstoffe von einander unterscheiden kann."

Formánek, in order to obtain his results, varied the concentrations of his solutions until each absorption band of a given substance became in succession as well defined as possible, so that the wave-lengths of their maxima might be read off with precision. This method is preëminently adapted to locating maxima, but it gives very little, if any, information relative to the absorption between and beyond the maxima, for bodies exhibiting marked

selective absorption, and it tells even less about substances presenting weak, general absorption. Another important respect in which Formánek's diagrams fail to give the data required by the first sentence of this section is that he confined his measurements to eye observations, unaided by phosphorescent screens, and hence he omitted the entire ultra-violet region. In fact, his wave-lengths have the limits  $420\mu\mu$  and  $741\mu\mu$ , i. e., from "above" the G line to a little "below" the  $\alpha$  line. Formánek used a prism spectroscope to the dispersion of which he gives no clue.

To fill in this gap in the then existing collections of absorption spectra the present research was begun in the spring of 1903. Its chief object is *to furnish graphical representations, on a normal scale of wave-lengths, of the absorption spectra, both in the visible and in the ultra-violet regions, of a reasonably large number of compounds.*

The most obvious use to which such a collection can be put is the production of color screens either for photographic work or for removing higher orders of spectra from the first order, in the case of diffraction gratings. It also makes possible the selection of such solutions as will transmit relatively narrow, and hence roughly monochromatic, regions of the spectrum. Such solutions are often convenient substitutes for somewhat elaborate pieces of apparatus which first disperse the light by a prism (or grating) and then permit any desired portion of the resulting spectrum alone to continue uninterrupted by means of a suitable slit and screens. Other directions in which the data given below may be of practical value need not be pointed out here.

#### SELECTION OF MATERIAL, APPARATUS, ETC.

That a great deal of time was consumed in constructing apparatus and in performing preliminary experiments is shown by the fact that, although the investigation was entered upon in the spring of 1903, it was not until July, 1904, that the first really satisfactory negative was obtained. Only aqueous solutions of the aniline dyes have been investigated up to the present time. As is well known, the position of an absorption band may be shifted within wide limits by varying the solvent;\* moreover, many aniline dyes are insoluble, or nearly so, in water. On this account it would have been desirable to have made use of the alcohols, benzol, and other organic compounds as solvents for the media under investigation. But difficulties were met with which were not overcome until the study of the dyes was completed. Chief among them may be mentioned the rapid evaporation of the fluid held between the quartz plates. Attempts were made to obviate the difficulty by painting the edges of the wedge with melted paraffin, but the heat of the spark was sufficient to drive off the greater part of the fluid before the

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\*See Nos. 158 and 165.

exposure was finished. Water is, however, the solvent generally used, and the easiest one to manage. It is moreover free from ultra-violet absorption, which is not true of the majority of the other solvents available, and all dyes which can be dissolved in water can be used for staining gelatin films. The gelatin can be dissolved in the solution of the dye and clean glass plates flowed with the warm solution, or an unexposed photographic plate, after preliminary treatment with thiosulphate of soda and thorough washing, may be stained with the solution of the dye. It is probable that the position of the absorption bands is the same in gelatin as in water, for the indices of refraction of the two media are very nearly the same.

#### ABSORBING MEDIA.

Because of their great variety, strong selective absorption, and general interest, aniline dyes and their related organic compounds were selected as best suited for the study contemplated.

#### DISPERSING SYSTEM.

In order to obtain reasonably normal spectra a spherical, concave, speculum grating, whose radius of curvature was 98.3 cm., was used. For the first order spectra and for short photographic exposures the astigmatism of the reflector did not produce deleterious effects. This was determined by actual measurements. The length of one line of the ruling was 1.96 cm., and the assemblage of lines covered 5.36 cm. The spectroscopic resolving power was 21,250 (2.125 inches with 10,000 lines per inch). The inconvenience of superposed higher orders will be mentioned later on. To obtain a general idea of the normality of the spectrograms and of the linear dispersion it may be stated that, by calculation one millimeter the center of which was at  $214.7\mu$ , or  $399.4\mu$ , or  $656.3\mu$ , covered 25.77, 25.84, and  $25.71 \text{ \AA. U.}$ , respectively, for the spectrum was designed to be normal at the air line  $399.4\mu$ .

#### PHOTOGRAPHIC MATERIAL.

Because of the short radius of curvature of the focal surface (about 49 cm.) celluloid films were employed in most cases. The films used throughout were M. A. Seed's "L-ortho cut negative films," size 5 by 7 inches. The emulsion is by no means equally sensitive over the field of wave-lengths studied, i. e., from  $0.2\mu$  to  $0.63\mu$ . The chief maximum of sensitiveness is in the yellow, about  $0.56\mu$ . A much weaker maximum is near  $0.49\mu$ . The middle of the less sensitive intervening region is very roughly  $0.52\mu$ .

For the short exposures given throughout, these films are not appreciably influenced by wave-lengths longer than about  $0.61\mu$ . The resultant effect of the Nernst glower and the Seed emulsion is best understood by referring to fig. 102, plate 26, for which the times of exposure were, in order, 2 seconds, 5 seconds, 15 seconds, 30 seconds, 1 minute, 2 minutes, and 3 minutes.

Various schemes to make the resultant action more uniform were tried and other makes of films were tested, but no improvement on the simple combination of the Seed emulsion and the Nernst glower resulted, therefore they were used almost exclusively. The Seed films are good in the ultra-violet as is shown by the fact that with an exposure of 5 minutes the aluminium line at  $185\mu$  was clearly recorded. To see if appreciable shifts in the apparent positions of the absorption bands were produced by the yellow maximum and the green minimum of the Seed films, negatives of the same absorbing medium, under exactly the same conditions, were taken on several different makes of films and plates which did not exhibit maxima and minima of sensitiveness for the same wave-lengths. Also, other and independent tests of this possible source of error were made. The conclusion was that no noticeable displacements of the bands were caused. However, in the cases of brown and other visibly colored solutions, exhibiting weak, general absorption, the observer of the appended positives must be careful to distinguish between true absorption and the spurious effects in the vicinity of  $0.52\mu$ .

In photographing bands in the orange and red, Cramer "Trichromatic" plates were found to be the best and hence they were used. The plates being plane they had to occupy a mean position with respect to the focal surface of the grating. Since only a comparatively small region of wave-lengths was thus recorded, no measurable errors were introduced. In fact, in the region considered, the second order ultra-violet of a discontinuous spectrum taken on a film and on a plate could be superposed line for line.

The developer used was a simple hydroquinone solution made up according to Jewell's formula.\*

#### SOURCES OF LIGHT.

For wave-lengths from "above"  $0.65\mu$  to "below"  $0.326\mu$ , and for exposures of about one minute, the Nernst glower was found to be the most satisfactory. Prevailing circumstances made desirable the use of 104 volt glowers on a circuit carrying about 133 cycles. The emissivity of the Nernst lamp varies so very greatly with the c. m. f. impressed upon its terminals that it was obligatory to keep in series with the glower a Thomson A.C. ammeter having a range from zero to two amperes and graduated directly to 0.02 ampere. Fluctuations of more than 0.02 ampere invariably resulted in a spoiled photograph, consequently boxes containing variable metallic resistance were maintained in series with the ammeter and thus, in spite of large changes in the load on the dynamo, due to other experimental circuits, it was possible to prevent the effective current in the filament from changing

\* L. E. Jewell. *Astrophys. Jour.*, v. xi, 1900, pp. 240-243.

by more than 0.01 ampere. The current was usually 0.8 ampere or a little less. The ammeter was appreciably more sensitive to small changes in the terminal voltage than a comparably graduated Thomson A. C. voltmeter, because the current shunted through the voltmeter was not negligible in comparison with the current which fed the glower. Among other sources the electric arc was given a fair trial and discarded for two reasons, first, because of the intensity of the carbon and cyanogen bands, and second, because of the inconveniences resulting from its unsteadiness and great emission of heat.

For wave-lengths between the strong ultra-violet of the Nernst glower and  $0.2\mu$  a spark discharge in air of about 1 cm. length was used. In obtaining the greater number of the negatives one electrode was composed of an alloy of equal parts by weight of cadmium and zinc and the other was made of sheet brass. The alloy wore away so rapidly that the brass electrode was employed to reduce the labor attendant upon sharpening the terminals.

The electrodes were given a form apparently not described before. As is very well known, many spectral lines, both weak and strong, produced by sparks between metallic surfaces extend only a short distance beyond the metal and hence do not offer a continuous source of light across the entire spark gap. In order to obtain a background of uniform intensity from edge to edge of the negatives it was necessary to use some scheme to nullify the effects of the non-uniformity of emission in the spark. One way of accomplishing this is to rapidly translate the electrodes (maintained at a fixed distance apart) back and forth parallel to the length of the slit of the spectrograph by some mechanical device.

The reciprocating action associated with this plan shakes the camera and grating to such an extent as to demand greater rigidity in the apparatus than it usually has. Therefore the electrodes were made in the shape of wedges or chisels with the sharp edges parallel to the slit. The well-known distribution of a rapidly alternating current in a conductor necessitated curving the edges of the electrodes, as is shown in fig. 1, which is  $\frac{11}{12}$  natural size. Due to the tearing away of the metal, and to various other causes, the innumerable thread-like sparks changed the positions of their ends so rapidly that the integrating action of the photographic film recorded a perfectly uniform negative for exposures of 15 seconds or more. The exposures generally lasted 75 seconds. The electrodes had to be kept sharp and smooth, for, when this was neglected, the elementary sparks persisted much longer in one position than in another and consequently caused streaks of varying intensity to run along the negatives parallel to their length, as can be seen in some of the positives reproduced in the appended plates, e.g., fig. 99, plate 25.

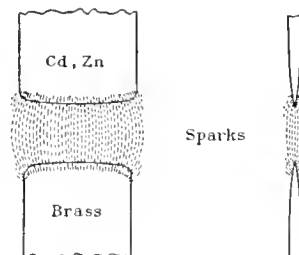


Fig. 1.—Flat and edge views.

The current for the spark was obtained in the following manner: An alternating e. m. f. of about 106 volts (133 cycles) was impressed on the terminals of an induction coil of unknown ratio of turns. Eight or nine amperes commonly flowed in the primary. The interrupter of the coil was thrown out of circuit and the coil therefore performed the functions of a transformer. In parallel with the secondary was placed a Leyden jar about 18 inches high and of unmeasured capacity. No auxiliary spark was introduced. The system could spark about 2.5 cm. in air between metallic points.

The great intensity of some of the lines characteristic of all the common metals tried (Al, Cd, Cu, Fe, Pb, Zn, etc.) made these metals undesirable for the present work. Cadmium and zinc were selected only because of the strong continuous background to which they give rise. Uranium, its salts or its earths were not used in this work because they are unmanageable. Naturally the pure metal in air burns to oxide at once; pitchblende can not be worked into a suitable shape (at least, for such specimens as we have been able to obtain); and, pitchblende is so very heterogeneous that the position of the spark can not be depended upon for an instant. To have employed a neutral atmosphere in conjunction with a reciprocating mechanism would have consumed, obviously, too much time and would have demanded too complicated, cumbersome and inconvenient an assemblage of apparatus.

#### THE CELL.

In order to show the variations in the absorption spectrum of a given substance when the thickness of the absorbing layer changed linearly, a wedge-shaped cell was constructed. Vessels made on this principle have been designed and used often before, notably by Ångström, Gladstone, Govi, Gibbs, Tumlirz, Hodgkinson, F. Melde, Hartley, and others.\* Nevertheless, because the precise form of the cell is supposedly new and certainly useful it may not be superfluous to enter into a detailed description of it here. This little piece of apparatus was designed so that the relative positions of the quartz surfaces through which the light entered into, and emerged from, the absorbing liquid could be varied at will, within certain limits. In other words, matters were so arranged that the liquid could be in the form either of a wedge, of variable angle, with zero thickness at the refracting edge, or of a prism of variable angle and finite depth throughout, or of a plane-parallel layer of changeable thickness. To satisfy these conditions it was convenient to rely upon gravitation to preserve certain parts of the cell in mutual contact. This in turn necessitated both the horizontal position of

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\* See H. Kayser, "Handbuch der Spectroscopie," v. III, pp. 58, 59.



the bottom of the cell and (because it was desirable to reduce the number of reflecting surfaces to a minimum) a vertical type of spectrograph.

The cell comprised five separable parts, as follows: (1) A brass framework upon which the other parts rested; (2) a transparent tray, without a lid, which confined the liquid in proper bounds; (3) a transparent boxlike system which gave the upper surface of the liquid the desired position; (4) a vulcanite framework to hold the last mentioned box in place; and (5) four mahogany pins or pegs to fasten the box to its framework.

(1) A side view of this framework is presented in figure 2. There were three micrometer screws, all of the same pitch, viz: 1 turn =  $\frac{1}{38}$  in.

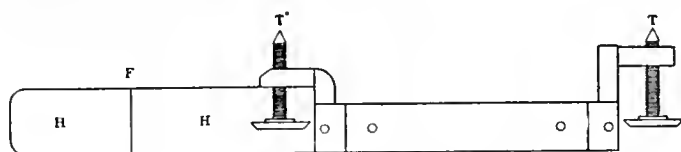


Fig. 2.—Four-fifths natural size.

$= 0.053$  cm. The heads of the screws were graduated, on their upper surfaces, in ten equal parts. The screw T was in the medial plane of the cell while the remaining screws (T' only is shown) were at the other end of the system, were equidistant from this plane, and were as far apart as possible. The micrometer screws called for vertical scales on the adjacent brass-work to count whole turns. The handle is denoted by HH. A black fiducial mark, F, on a white ground, enabled the experimenter to tell what position the cell occupied with reference to the length of the slit of the spectrograph. The lower end of F moved over a scale parallel to the slit and in the plane of the jaws of the latter. The flange at the bottom of the framework was made of brass only 0.014 cm. thick so that the absorbing medium might be as near the slit as possible.

(2) An accurately ground, plane-parallel plate of quartz 40 mm. long, 18.5 mm. wide, and 2 mm. thick had cemented to its periphery four rectangular sheets of thin glass 8 mm. high. Hence, the greatest depth of liquid which could be studied by the aid of this cell was 6 mm.

(3) In figure 3, *a*, *b*, *c*, and *d* designate the vertices of the section of a quartz plate, made by a plane perpendicular to the plane the trace of which is the line *ad*. *ab* was 2 mm., *ad* was 34.8 mm., and the angle between the planes of *ad* and *bc* was 55 minutes of arc. The horizontal width of the wedge was 10 mm. Glass walls surrounded three sides of the wedge, as the outline indicates. The reason for using the quartz wedge was to counteract the deviation and dispersion produced by the solution in the cell. The angle of the liquid wedge could be varied until the deviation effected by the quartz wedge nullified the average action of the absorbing solution. At first it was supposed that with liquid wedges of 15 or so minutes of arc a plane-parallel quartz plate could be used successfully instead

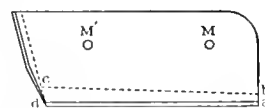


Fig. 3.—Four-fifths nat. size.

of the quartz wedge. This was true for some dyes but for concentrated solutions of certain other dyes (notably the sodium salt of *p*-methoxy-toluene-azo- $\beta$ -naphthol-di-sulphonic acid) some compensating system was absolutely necessary. Finally, the quartz wedge was made with the utmost care by an expert optician, special pains being taken to have the edge through *d*, perpendicular to the plane *abcd*, as sharply defined as possible, and the surfaces whose traces are denoted by *ad* and *bc* were accurately plane.

(4) Figure 4 presents a side view and an end view of the vulcanite frame into which the quasi-box just described fitted. This frame was shaped

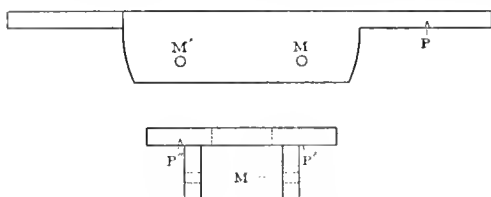


Fig. 4.—Four-fifths natural size.

out of a single block of vulcanite, for experience showed that a cemented system of several pieces was not durable; also a dielectric was needed to keep the sparks from jumping to the screws. P indicates a little depression which fitted over the point of the screw T. P' designates the end of a straight line along which the rounded extremity of the screw T' slid. P'' is the cross-section of a shallow, V-shaped groove along which the pointed end of the third screw, T'', likewise slid. The perforations M, M', etc., correspond to each other and to the associated wooden pegs mentioned above as (5).

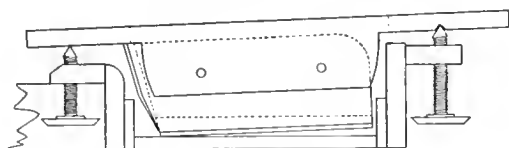


Fig. 5.

Figure 5 is an unconventional sketch of the cell when completely assembled. A cell of the construction just described is very well suited to the study of thin layers of solutions in solvents of relatively high boiling-points, such as water and amyl alcohol, but, unless inclosed in some suitable vessel, it is not applicable to solvents of lower boiling-points like ethyl alcohol, ether, chloroform, etc.

#### CEMENTS.

A few words concerning cements may not be superfluous because a great many receipts were tried and none was considered entirely satisfactory. No single cement was found which satisfied the following three necessary conditions: (a) Of being unaffected by hot or cold water; (b) of being insoluble in the alcohols, ether, chloroform, carbon bisulphide, etc.; (c) of drying or setting in three or four days, at most.

The plan used by Prof. H. N. Morse, in waterproofing cells for the study of osmotic pressure, gave the best results and hence it was followed

in fastening together the quartz and glass parts of the cell described in the last section. These parts were first fastened together with Khotinsky cement in the usual way, that is, by heating them in an air bath, to any convenient temperature above the melting point of this cement, and by heating a stick of the adhesive mixture in a Bunsen flame and then applying it to the surfaces of the hot quartz and glass.

Since this resinous cement is soluble in ethyl and amyl alcohol and other solvents, and because it is attacked by various liquids, such as an aqueous solution of potassium permanganate, it was necessary to coat the exposed surfaces of the cement with something which was chemically inert towards the solutions to be studied. Such a substance is a solution of rubber in carbon bisulphide. This solution was made and used as follows: From an adequate length of black, soft, rubber connecting-tubing segments about 2 cm. long were cut and heated in an evaporating dish over a Bunsen flame until the sections fused, ran together, and formed a very sticky, viscous liquid. (A single long piece of tubing does not liquefy at all satisfactorily.) The liquid state persisted after the contents of the evaporating dish had been allowed to cool down to about room temperature. Carbon bisulphide was next poured into the dish and the contents of the latter were stirred until a homogeneous solution resulted.

The relative proportions of the carbon bisulphide and rubber used were immaterial and were determined by convenience only. The solution can be retained indefinitely in a tightly stoppered bottle and used whenever needed. A thin layer of the solution was painted over the Khotinsky cement, after which the quartz-glass system was heated in an air bath at about 100° C. until the layer became dry and hard, and was no longer sticky. (Of course, during the first part of the process the transparent elements of the cell had to fit over a suitable wooden "form," because Khotinsky cement softens too much at 100° C. to maintain objects in their proper relative positions.) After this another thin coat of the rubber solution was applied and the heating continued. This succession of operations was repeated until a thick, hard, dark-brown covering for the joints was obtained. It then made little difference whether the original cement were present or not, as the hard rubber held the quartz and glass together very satisfactorily.

A cement which dissolves readily in water and in acetic acid but which is not affected by ethyl alcohol, amyl alcohol, carbon bisulphide, glycerin, chloroform, ether, benzol, nitrobenzol, aniline oil B, benzaldehyde, toluol, etc., is made by dissolving 2 pounds of pure gelatin in one quart of water and adding to the resulting solution 7 ounces of nitric acid (sp. gr. 1.35 to 1.42). The final solution is colorless and when applied in thin layers dries in a day or so. It is called Dumoulin's liquid glue. This glue does not keep well,



even in a tightly stoppered bottle, and is best made up fresh just before being applied as an adhesive.

Since the completion of the experimental work on the aniline dyes a cell, in the construction of which no cement at all was employed, has been designed and successfully used by one of us.\* This cell could retain any liquids which would not attack glass and quartz and, although it was designed to confine the solutions in plane-parallel layers, nevertheless, the principles involved in its construction were such as to admit of extension to the production of a cell which would be wedge-shaped in the interior and would, at the same time, hold organic solvents, prevent evaporation, etc.

### THE SPECTROGRAPH.

The essential parts of a vertical section of the spectrograph are outlined in figure 6. They may be tersely described, with the aid of symbols, as follows: In the first place, the elements of the system were adjustable in every respect. Light from the Nernst filament, N, was focused by the concave speculum mirror, R, on the slit, S, whence it continued to the grating, G, from which a portion of it was dispersed in the direction of the sensitized film, F. The distances from the middle of the slit to the centers of the mirror and grating were respectively about 89.5 cm. and 97.1 cm. The electrodes, E, were usually at the distance of 4.2 cm. above the slit and they did not interfere with the passage of the light from the reflector to the slit. No lenses or other reflectors were used. The micrometer head at M indicated the separation of the slit-jaws. Q and Q' denote a screen system such that when Q was vertical the passage of light from the grating to the camera was not interfered with, whereas when Q was horizontal only ultra-violet light of shorter wave-length than  $0.4\mu$  could reach the photographic film. PP is a horizontal platform with a scale along its front edge. By sliding projecting, horizontal, opaque screens of various widths along this platform it was possible to cut out completely any region or regions of wave-lengths desired.

In making certain tests, the platform and sliding screens were very convenient. L is the section of a thin, black, metal shutter capable of motion in a horizontal direction and hence at right angles to the length of the photographic films; in other words, parallel to the slit and to the rulings of the grating. A number of long, rectangular slots or openings, suitably spaced and proportioned, were present in this screen so that strips of different widths of the films or plates could be exposed to the light from the grating without causing any displacement of the sensitized surfaces with refer-

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\*The description of the details of the cell is given on pages 241 to 243 of Publication No. 60 of the Carnegie Institution of Washington, entitled: Hydrates in Aqueous Solution. By Harry C. Jones.

ence to the grating and slit. This was necessary for impressing comparison spectra, etc. H and H' suggest the rack-and-pinion system by the aid of which the films could have unexposed portions brought successively opposite to some selected opening in the slide-screen L. D and D' denote two of

the four doors which gave access to the interior of the spectrograph, and which made it possible to close up the camera light-tight, while making various adjustments with the rest of the system. The camera was made so that, when it contained neither a film nor a plate, it was possible for the experimenter to look directly at the grating and to make observations with the assistance of an eye-piece.

Certain black-on-white scales and ruby-glass windows (Z, for example) enabled the experimenter to know the precise relative positions of the various accessories on the interior of the spectrograph, when the entire system was shut up and exposures were being made. Numerous dull black diaphragms and screens ( $A_1, A_2, A_3, A_4, A_5$ , etc.) protected the photographic film from the unusable light which came from the central image, I, and from all the spectra except the one desired.  $U_1$  and  $O_1$  give the extreme rays of so much of the first order spectrum as was studied, that is,  $U_1$  and  $O_1$  correspond respectively to about  $0.20\mu$  and  $0.625\mu$ . Obviously, the spectrograph was dull black, both inside and out, and contained plaited black velvet in appropriate places. A general idea of the size of the apparatus may be derived from the following dimensions: From R to the plane of BC = 198.5 cm.; BC = 34.5 cm.; the bottom edge perpendicular to BC = 27.5 cm.; BJ = 116 cm.; and JK = 29 cm.

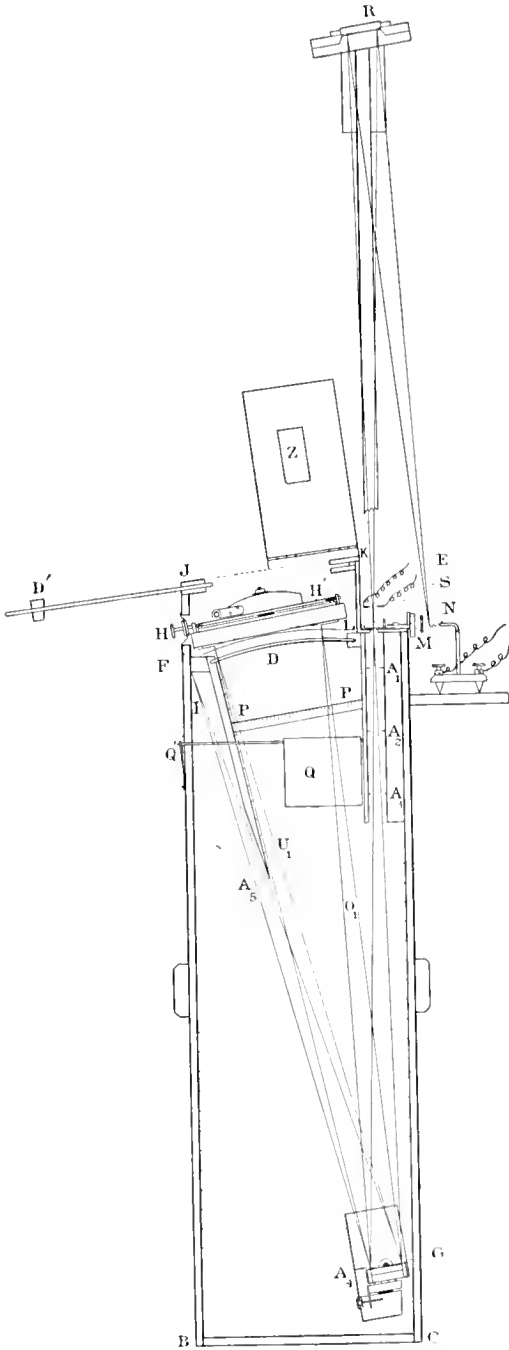


Fig. 6.—One-tenth natural size.

**MANNER OF EXPERIMENTING.**

## SOLUTIONS.

A small, known mass of a selected dye was carefully weighed on a chemical balance, and put at the bottom of a medium-sized test-tube. Then distilled water was run from a burette into the test-tube, and the latter shaken up from time to time, until the resulting solution appeared to have the proper concentration. As would be expected, practice produced skill in judging absorption of visible light, but to get the right concentration with respect to ultra-violet light was not always so easy. The greatest error in measuring the solvents was about 0.2 per cent. Since the concentrations are only intended to serve as general guides to an understanding of the spectrograms, a higher degree of accuracy would have been superfluous. Neither was there any reason, in general, for noting the volume of *solution* which contained a known number of grams of pure solvent; in other words, changes in volume due to the processes of solution were not regarded.

## ADJUSTMENT OF THE CELL.

Especial care was taken to remove all coloring matter from the cell before introducing another solution into it. Dust caused more trouble than anything else. After cleaning the quartz and glass elements of the cell the various parts of the latter were assembled and, when a *prism* of liquid was to be studied, the micrometer screws regulated in the following manner: All the screws were turned down so as not to touch the vulcanite framework, and thus to cause the quartz wedge to rest on the quartz plate. Then the screw T had its point elevated again and again until it just touched the deepest part of the depression P. (*See* figures 2, 3, 4, and 5.) This condition was attained by gently rocking the system around the edge *d* of the quartz wedge, somewhat after the fashion of experimenting with certain types of spherometer. Thus the zero position of the cell was determined, before each experiment, of course. Next, guided by the circular and plane scales, the observer turned up the screw T until the desired angle, between the wedge and plate, was known to obtain. After this, the screw corresponding to T' was turned up until its tip projected far enough into the groove P'' to prevent the quartz wedge and its accessories from sliding over the quartz plate around the point T as pivot, but yet not far enough to raise the vulcanite frame the least bit. Finally, a small amount of the solution was poured into the cell and the latter was then placed on the very thin brass sheet which rested upon and protected the jaws of the slit.

As soon as the cell was placed over the slit and the glower had been lighted the cell was moved forward and backward, parallel to the slit, while one edge of the field of view was examined with an eye-piece, until a position of the cell was obtained for which the light passing through the quartz wedge

at its refracting edge ( $d$  of figure 3) illuminated the very limit of the field of view as seen through the chosen slot of the shutter (L of figure 6). The position of the mark on the handle of the cell (F of figure 2), with respect to the horizontal scale in the plane of the slit-jaws, was then read off. If the cell were then moved, ever so little, in one direction the width of the brightly illuminated field could be seen to be less than the opening in the shutter; whereas, if the cell were translated in the opposite sense no increase in the width of the illuminated field occurred. At this opportunity, eye-observations of the absorption between  $0.400\mu$  and  $0.625\mu$  were always made and the facts recorded.

When the concentration of the liquid in the cell was much too great or far too small this instrument had to be cleansed and filled with a solution of more suitable absorbing power, obviously, but when the concentration was not too remote from the best value the effective depth of the cell was varied until the desired result was obtained.

All three screws were raised and regulated in an obvious manner when prisms of liquid having nowhere infinitesimal thickness were wanted. When layers of liquid of uniform depth were studied a system much like that shown in figure 3, but which had for bottom a plane-parallel plate of quartz 2 mm. thick, was substituted for the quartz-wedge system.

#### CALIBRATION OF THE CELL.

The diedral angles formed by the cell were calculated from the dimensions of the instrument, and also from measurements made with a spectrometer.

#### EXPOSURES AND SPECTROGRAMS.

The majority of the spectrograms consist of three distinct photographs taken side by side and as close together as possible. (*See the plates.*) The width of each photograph was practically the same as the width of the opening in the shutter L. Numerous trials showed that this field of view was completely filled with light, with no overlapping on the grating-side of the opaque portions of the shutter, when the length of the slit was diaphragmed down to 10.5 mm. Consequently, the slit was limited to a length of a very little more than this number and the cell was moved along exactly 10.5 mm. between the taking of two adjacent photographic strips on the same film. By this means, the thickness of absorbing liquid through which the light passed to the very edge of one photographic strip was equal to the thickness subsequently traversed by the light which recorded itself at the contiguous edge of the adjacent strip. Of course, the best appearing records were obtained when the film holder, actuated by the rack-and-pinion system, was moved, by an amount exactly equal to the width of the opening in the shutter. A casual inspection of the positives reproduced in the appended

plates shows that mechanical shifts, in wave-lengths, of the strips on one complete spectrogram, with reference to one another, exist. This may mar the appearance of the photographs somewhat, but the ultra-violet spark lines show the magnitude of the displacements so that corrections can be made, and hence the ultimate scientific value of the results is not decreased.

The order of events in taking a complete negative of *three* strips was invariably as follows: The thickest layer of absorbing liquid was over the opening of the slit first, then the intermediate layer, and last of all, the thinnest layer, which usually tapered to infinitesimal depth. This sequence enabled the comparison spectrum to be taken by moving the shutter, L, without jarring the film-holder, so as to minimize the shift of this spectrum relative to the adjacent photographic strip. For negatives of more than three strips precisely the reverse succession was adopted because it was easier to commence with the cell in adjustment and then to raise the quartz wedge parallel to itself than to lower all three micrometer screws by the same number of turns until the quartz wedge just barely came into contact with the quartz bottom of the cell. With the screen Q horizontal the first exposure with the spark was taken. The screen was lowered and the second exposure was made, this time with the Nernst glower. These two exposures produced the first of the three photographic strips. Next the film-holder and cell were moved the proper distances, as explained above. The glower and spark exposures followed in the order named. After again moving the film-holder and cell, the fifth and sixth exposures were produced by the spark and glower respectively. Finally the cell and diaphragm were removed from the slit, another opening in the shutter was adjusted before the film, and the comparison spectrum impressed. In general, the glower exposures lasted 60 seconds, the ultra-violet exposures 75 seconds, and the comparison exposures 35 seconds. The width of the slit was always 0.008 cm. In any one complete spectrogram the exposures to the Nernst light were all equal to each other and those for the ultra-violet were related to one another in the same manner. Experience showed that the intervals 60 and 75 seconds were best suited to cause the overlapping ends of the photographic impressions to blend as if they had been produced simultaneously by light from a single source. With the longest exposures used, the light from the glower did not affect the films and plates for wave-lengths as short as  $0.315\mu$  and, since the field photographed did not comprise wave-lengths longer than  $0.63\mu$ , there was no trouble produced by the ultra-violet of the second order. The screen Q took care of this matter so far as the spark exposures were concerned. Figures 14 and 15, plate 4, indicate how the processes just explained can be extended to negatives as wide as may be desirable and hence to as deep layers of absorbing liquid as may be wished.\*

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\*Of course, a cell deeper than 6 mm. would be necessary if the matter were pushed very far.



## RESULTS.

## INTERPRETATION OF THE CURVES.

If the distances from the edge of a positive which is adjacent to the comparison spectrum (which edge therefore corresponds to zero depth of liquid in the cell) to arbitrary points on the boundary of a sharply-defined absorption curve be called ordinates, and if wave-lengths be considered as abscissæ, we may say that the absorption constants\* associated with any two chosen wave-lengths are inversely proportional to the ordinates belonging to these wave-lengths. This statement involves certain assumptions, about emission curves and sensibility curves, a discussion of which will not be given here.

If the edge of an absorption band is a straight line at right angles to the length of the picture it means that the position of this side of the band will not appreciably change with wide variations in the concentration of the solution; in other words, the limit of absorption will remain at the same wave-length regardless of the concentration. This is roughly the case in figs. 4 and 15 of plates 1 and 4 at the respective wave-lengths  $0.29\mu$  and  $0.515\mu$ , and for most of the narrow bands of figs. 96, 100, and 101. If this condition holds for all the bands of a given substance, which are within or near the confines of the visible spectrum, the color of the light transmitted by the solution will be the same no matter how much the concentration be varied. This is well illustrated by solutions of the salts of neodymium and praseodymium.

When the boundary of an absorption band is a straight line inclined to the axis of wave-lengths it may be inferred that the limit of the band will be displaced in proportion to the change of concentration, and that the factor of proportionality depends upon the angle which the line makes with the axis of abscissæ. This is exemplified in fig. 45, plate 12, by the portions of the band, at wave-length  $0.47\mu$  corresponding to the thicker layers of liquid.

In like manner, the general relation between the displacements of the limits of absorption and the associated changes in concentration may be easily inferred when the confines of the absorption bands are curved either convex or concave.

## EXPLANATION OF THE TABLES.

Two plans suggest themselves for the sequence of the experimental data, viz: (a) To classify the material on the basis of the characteristics of the absorption spectra, i. e., the succession, intensity, etc., of the bands and regions of absorption; (b) to arrange the results according to the chemical

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\* $\kappa_{\lambda}$  in  $I'_{\lambda} = I_{\lambda} e^{-\kappa_{\lambda} l}$

nature of the absorbing media. Because the first method conforms more closely to the professed object of the present research than the second, every scheme consistent with it was tried which suggested itself. The great number of combinations on the negatives of the effects of weak, general absorption with definite, intense bands, combined with more or less uncertainty as to the interpretation of the negatives in the region for which the source of the discontinuous spectrum had to be used, made it impossible to find a satisfactory permutation of the photographic records. Consequently the second plan suggested above was followed as far as the text is concerned. The spectrograms, on the contrary, are arranged, as far as possible, so as not to have widely different absorption spectra succeed one another on the same plate.\* The organic coloring matters succeed one another in the same order as is given to them in the English translation by A. G. Green of a book by G. Schultz and P. Julius entitled "A Systematic Survey of the Organic Colouring Matters" (Macmillan & Co., London, 1904). This connection between the contents of the volume just named and the material recorded below has the advantage of making it easy to find out many things about the dyes which can not be appropriately given here, such as the names of their discoverers, their literature, patents, methods of preparation, their behavior with various reagents, chemical constitution, etc.

The descriptive tables following this explanatory section present the experimental results in the following order:

(1) The absorption of a small number of interesting intermediate products, so-called, arranged according to the alphabetical order of their names.

(2) The absorption of such dyes as were studied and were capable of identification with the dyes discussed in the book by Schultz & Julius.

(3) The absorption of such dyes as were not unquestionably the same as any given in the reference volume. The accounts of these dyes follow the alphabetical order of their *commercial* names.

(4) The absorption of certain miscellaneous objects of more or less interest, in alphabetical order.

Whenever a number without qualification is given to a substance it refers to the present account, but when a number is quoted from the volume by Schultz & Julius attention is called to the fact by the abbreviation S. & J.

In the brief account of any one dye the details are presented in the sequence explained by the following sentences:

First. The arbitrary number of the substance in the present list is given.

Second. The commercial name of each substance is recorded precisely as it was labeled by the firm which furnished the coloring matter. When

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\*Plate 2 is an exception to this statement.

two firms sent the same dye under the same or under different names the circumstance is explicitly presented.

Third. Immediately after the commercial name that of the factory is given. The dyes were obtained from three sources. Both the Actiengesellschaft für Anilinfabrikation and Meister, Lucius & Brüning presented a large number of dyes of their manufacture to the Johns Hopkins University. The other dyes were purchased from the firm of Eimer & Amend, New York.

The following abbreviations are used throughout.

[A.] Actiengesellschaft für Anilinfabrikation, Berlin (The Berlin Aniline Co.).

[A. A. C.] The Albany Aniline Color Works, Albany, New York.

[B.] Badische Anilin-und Sodafabrik, Ludwigshafen am Rhein (The Baden Co.).

[By.] Farbenfabriken vorm. Fr. Bayer & Co., Elberfeld (The Bayer Co.).

[C.] Leopold Cassella & Co., Frankfurt am Main.

[D.] Dahl & Co., Barmen.

[D. H.] L. Dnrand, Huguenin & Co., Basle and Hüningen.

[G.] J. R. Geigy, Basle.

[I.] Société pour l'Industrie Chimique (formerly Bindschedler & Busch), Basle.

[K.] Kalle & Co., Biebrich am Rhein.

[M.] Farbwerke vorm. Meister, Lucius & Brüning, Höchst am Main (Meister, Lucius & Brüning, Limited).

[O.] K. Oehler, Offenbach am Main.

[P.] Société Anonyme des Matières Colorantes de St. Denis, Paris.

Fourth. The chemical name of the absorbing medium is given.

Fifth. Reference is made either to the figure (or figures) and plate which belong to the substance under discussion itself or to a figure which is very much like the spectrograms of the dye considered.

Sixth. When possible, the number of the dye or the page of the intermediate product, as found in the volume of Schultz & Julius, is recorded.

Seventh. The color and superficial character of the dry coloring matter is suggested.

Eighth. The color of the solution as observed in a test-tube is followed by the color in the cell. The change of color with thickness is often significant.

Ninth. Then follows the concentration in grams of dry solvent in a liter of solvent. The term "saturated" is to be understood in its general, practical sense and not in the almost unattainable, theoretical sense. Parenthetical, qualifying words, such as "(heated, filtered)," call attention to the fact that the substance does not dissolve readily in water, or that the solution contained gritty, foreign material, etc.

Tenth. Next is given the angle between the quartz plates forming the top and bottom of the various cells used. In the same line the numbers denote in order the minimum and maximum depths of solution through which the light passed before acting upon the outer limits of the negative. The intermediate thicknesses vary linearly, of course. The same angle is not

always associated with the same maximum depth, even when the minimum thickness is unchanged, because several cells of different dimensions were employed.

Eleventh. Finally, a brief account of the most noticeable characteristics of the absorption spectrum, between the limits  $0.20\mu$  and  $0.63\mu$ , is furnished.

The results of eye-observations of the absorption spectra come first and serve as checks on the photographic records. The data obtained visually are qualitatively reliable for all strong bands between  $0.40\mu$  and  $0.63\mu$ . For cases of very weak, general absorption much less importance must be ascribed to the visual results because, unfortunately, the cells were not constructed so as to present side by side, in the field of view, two spectra, the one of the light after passing through the absorbing solution, the other of the unabsorbed light direct from the Nernst glower.

When the solution is fluorescent, or decomposes when ultra-violet light falls upon it, or possesses a characteristic odor, etc., the facts are noted. That the spectrograms are not distorted by the presence of fluorescent light, but give as true records of the absorption spectra of fluorescent compounds as they do for non-fluorescent solutions, was ascertained by direct experiments. (In particular, see the record for solution No. 107.)

Lastly, the *approximate* wave-lengths of the maxima and minima of absorption, as obtained from the spectrograms, are given, beginning near  $0.20\mu$  and continuing to  $0.63\mu$ . When the wave-lengths of the "ends" of a region of absorption are given they obviously have significance only under the conditions of thickness of absorbing layer, of concentration, of length of photographic exposure, etc., which prevailed at the time when the spectrogram was taken. The maxima are not subject to the same limitations. The fact that the Seed films can produce spurious absorption bands in the green must be again emphasized. (See figure 102, plate 26.)

When the end of the spectrogram, which marks the fading away of the sensitiveness of the emulsion from the yellow to the orange, is practically a straight line perpendicular to the length of the spectrogram it means that there is no appreciable general absorption in this locality, but when the limit just specified is approximately a right line inclined at an obtuse angle to the positive direction of the axis of wave-lengths it signifies that appreciable general absorption is present in this region.

## TABULATED DATA OF ABSORPTION.

### INTERMEDIATE PRODUCTS.

1. Amidonaphtholdisulphonic Acid H. (M.)  
Fig. 1, pl. 1; pp. 57 and 58, S. & J.  
Grayish-white lumps. In solution brownish yellow, colorless.  
Saturated.  
Angle 27.3'. Depth 0 to 0.25 mm.  
No visible absorption. Intense blue fluorescence. Ultra-violet absorption ends about 0.347 $\mu$ .
2.  $\beta$ -Naphtholdisulphonic Acid G. (M.)  
Figs. 2 and 5, pl. 1; p. 51, S. & J.  
Pinkish-white powder. In solution colorless.  
Saturated.  
Angle 27.3'. Depth 0 to 0.25 mm.  
No visible absorption. Intense blue fluorescence. Absorption ends very definitely and follows approximately a straight line from 0.346 $\mu$  to 0.356 $\mu$ . Fig. 5 shows absorption exhibited by a solution made by diluting a certain volume of the saturated solution to eight times its original value.
3.  $p$ -Nitraniline. (Powder, "extra.") (M.)  
Page 12, S. & J.  
Lemon-yellow powder. In solution yellow, faint yellow.  
Saturated.  
Angle 37.1'. Depth 0 to 0.34 mm.  
No visible absorption is produced by a column 6 cm. deep. Entire ultra-violet absorption is weak. A region of slight absorption from 0.20 $\mu$  to 0.255 $\mu$  is followed by transparency as far as 0.34 $\mu$ . Faint absorption extends from 0.34 $\mu$  to 0.40 $\mu$ . From 0.40 $\mu$  to 0.63 $\mu$  no absorption is noticeable.
4.  $o$ -Nitrobenzaldehyde. (M.)  
Page 61, S. & J.  
White needles. In solution colorless.  
Saturated.  
Angle 31.2'. Depth 0 to 0.29 mm.  
Extremely weak absorption from 0.20 $\mu$  to 0.24 $\mu$ . Transparent from 0.24 $\mu$  to 0.63 $\mu$ .
5.  $p$ -Nitrosodimethylaniline.  
Fig. 3, pl. 1; p. 32, S. & J.  
Dark-green, crystalline powder. In solution brownish yellow, clear yellow.  
Saturated.  
Angle 23.4'. Depth 0 to 0.21 mm.
5.  $p$ -Nitrosodimethylaniline—*Continued*.  
Strong absorption in violet and blue increasing towards the ultra-violet. A remarkably transparent region extends from 0.30 $\mu$  to 0.375 $\mu$ . All the strong lines between 0.324 $\mu$  and 0.363 $\mu$  are transmitted with almost no decrease in intensity.\* A very round band stretches from 0.375 $\mu$  to 0.448 $\mu$  with its maximum at 0.432 $\mu$ . Complete transparency from 0.49 $\mu$  to 0.63 $\mu$ .
6. Resorcine (techn. pure). (M.)  
Fig. 4, pl. 1; p. 45, S. & J.  
White, crystalline lumps. In solution colorless.  
Nearly saturated.  
Angle 29.3'. Depth 0 to 0.27 mm.  
No visible absorption. Very faint yellow in a layer a decimeter thick. Absorption ends very abruptly and shows an almost vertical right line determined by 0.287 $\mu$  and 0.293 $\mu$ .

### COLORING MATTERS.

7. Naphthol Yellow. (A.) Naphthol Yellow S. (M.) Sodium salt of dinitro- $\alpha$ -naphthol- $\beta$ -monosulphonic acid.  
Fig. 42, pl. 11; No. 4, S. & J.  
Orange-yellow powder. In solution brownish yellow, pure yellow.  
Saturated (heated).  
Angle 31.2'. Depth 0 to 0.29 mm.  
Intense band in violet, ultra-violet side invisible. Absorption decreases from 0.20 $\mu$  towards 0.335 $\mu$ . Transparent region around 0.335 $\mu$ . A pair of overlapping bands extends from about 0.345 $\mu$  to 0.465 $\mu$ . Their maximum absorption is at 0.385 $\mu$  and their least absorption is at 0.41 $\mu$ . Very transparent from 0.465 $\mu$  to beyond 0.63 $\mu$ .
8. Aurantia. Ammonium salt of hexanitrodiphenylamine.  
Fig. 39, pl. 10; No. 6, S. & J.  
Reddish-brown crystals. In solution dull red, yellow.  
10 g. per liter (filtered).  
Angle 42.5'. Depth 0 to 0.36 mm.  
General absorption in violet. Absorption decreases from 0.20 $\mu$  towards 0.28 $\mu$ . Transparent region from 0.28 $\mu$  to 0.33 $\mu$ . Wide band from 0.33 $\mu$  to 0.49 $\mu$  with its maximum

\* R. W. Wood, "On Screens Transparent only to Ultra-Violet Light and their use in Spectrum Photography." *Phil. Mag.*, v. 5, Feb., 1903, pp. 257-263.

8. Aurantia—*Continued.*

at  $0.41\mu$ . As the concentration increases the absorption encroaches much faster on the transparent region in the ultra-violet than on the limit in the yellow. Very transparent to yellow and orange.

## 9. Fast Yellow. (B.) Sodium salt of amidoazotoluene-disulphonic acid.

Somewhat similar to fig. 40, pl. 10; No. 9, S. & J.

Brownish-yellow powder. In solution brownish yellow, yellow.

15 g. per liter.

Angle  $23.4'$ . Depth 0 to 0.21 mm.

Absorption in violet and blue. The region of partial transmission in the ultra-violet is not as complete for solution No. 9 as for solution No. 32. Also the boundaries of the violet band are somewhat more definite for the former solution than for the latter. The less refrangible side of this band is more like the corresponding region for solution No. 129, fig. 13, pl. 3. Absorption decreases gradually from  $0.20\mu$  to semi-transparency at about  $0.34\mu$ . A wide, diffuse band extends from this region to about  $0.475\mu$ . Its maximum is at  $0.40\mu$ . Transparent from  $0.475\mu$  to  $0.63\mu$ .

10. Orange G. (A.) Sodium salt of benzene-azo- $\beta$ -naphthol-disulphonic acid G. Fig. 30, pl. 8; No. 14, S. & J.

Yellowish-red powder. In solution red, yellow.

Saturated (heated).

Angle  $21.3'$ . Depth 0 to 0.18 mm.

Strong absorption in blue and green. Sharp on yellow edge. Two ultra-violet bands meet at about  $0.29\mu$  in a semi-transparent spot. The maximum of the less refrangible band is  $0.325\mu$ . This strong band meets a very weak one at  $0.365\mu$ . The center of the weak band is  $0.39\mu$ . The weak band joins an intense one at  $0.42\mu$ . This last band joins a still stronger band, from which it is not resolved, at  $0.485\mu$ . The maximum of the stronger band is at  $0.505\mu$ . Absorption ceases at  $0.53\mu$ . Complete transparency to  $0.63\mu$ .

11. Ponceau 2 G. (M.) Sodium salt of benzene-azo- $\beta$ -naphthol-disulphonic acid R.11. Ponceau 2 G—*Continued.*

Fig. 6, pl. 2; No. 15, S. & J.

Bright-red powder. In solution yellowish red, yellow.

7 g. per liter (filtered).

Angle  $27.3'$ . Depth 0 to 0.25 mm.

Comparatively weak band in the blue-green, with a shadowy, fainter companion on the yellow side. Absorption decreases gradually from  $0.20\mu$  to  $0.34\mu$ . The nearly transparent region from  $0.34\mu$  to  $0.44\mu$  is interrupted by a very faint band having its maximum at  $0.39\mu$ . The pair of stronger bands extends from  $0.44\mu$  to  $0.545\mu$ . Transparent from  $0.545\mu$  to  $0.63\mu$ . Same empirical formula as No. 10. No. 10 is derived from the G acid, while No. 11 is a salt of the R acid.

## 12. Chrysoïdine. Hydrochloride of diamidoazobenzene.

Fig. 7, pl. 2; No. 17, S. & J.

Reddish-brown powder. In solution brown, yellow.

10 g. per liter (filtered).

Angle  $23.4'$ . Depth 0 to 0.21 mm.

Absorption in violet, blue, and green with maximum in the indigo. Absorption decreases from  $0.20\mu$  to  $0.33\mu$ . Transparent from  $0.33\mu$  to  $0.36\mu$ . A pair of broad, unseparated bands absorbs from  $0.36\mu$  to  $0.54\mu$ . The band of greater refrangibility is the more intense and has its maximum at  $0.43\mu$ . Transparent from  $0.54\mu$  to  $0.63\mu$ . The less refrangible band disappears first on dilution. A five-strip negative shows that the outer boundaries of the pair of bands are steep and definite.

13. Chromotrope 6 B. (M.) Sodium salt of *p*-acetamidobenzene-azo-1:8-dioxynaphthalene disulphonic acid.

Fig. 8, pl. 2; No. 38, S. & J.

Grayish-brown powder. In solution red, pink.

5.71 g. per liter.

Angle  $11.7'$ . Depth 0 to 0.11 mm.

Strong absorption in green-yellow.

Transparent from  $0.35\mu$  to  $0.465\mu$ . A strong band has its beginning at  $0.465\mu$  and its maximum at  $0.515\mu$ . The less refrangible side joins a weak companion band extending into the orange and red. More dilute solutions show that the intense band is symmetrical with respect to its max-

13. Chromotrope 6 B—*Continued*.  
inum until it joins the associated band. More concentrated solutions show very distinctly the weaker band in the orange-red.
14. Azo Coccine 2 R. (A.) Sodium salt of xylene-azo- $\alpha$ -naphthol- $p$ -sulphonic acid.  
Fig. 9, pl. 2; No. 50, S. & J.  
Reddish-brown powder. In solution salmon pink, salmon pink. Saturated (heated).  
Angle 27.3'. Depth 0 to 0.25 mm.  
Narrow band in the blue-green. An absorption band of very indefinite edges extends from about 0.48 $\mu$  to 0.53 $\mu$  with its maximum at 0.505 $\mu$ . Transparent from 0.53 $\mu$  to 0.63 $\mu$ .
15. Brilliant Orange G. (M.) Sodium salt of xylene-azo- $\beta$ -naphthol-mono - sulphonic acid.  
Fig. 31, pl. 8; No. 54, S. & J.  
Cinnabar-red powder. In solution yellowish red, deep yellow.  
7 g. per liter.  
Angle 23.4'. Depth 0 to 0.21 mm.  
Intense absorption in blue-green and blue. Very sharp on the yellow side. Absorption decreases from 0.20 $\mu$  to weak absorption at 0.295 $\mu$ , then increases to maximum absorption at 0.32 $\mu$ . At 0.355 $\mu$  semi-transparency obtains. A definite band has its maximum at 0.395 $\mu$  and joins the next band at 0.43 $\mu$ . The next band has its maximum at 0.48 $\mu$  and joins the adjacent band at 0.505 $\mu$ . The final band has a maximum at 0.52 $\mu$ . Absorption ends at 0.545 $\mu$ . Complete transparency to 0.63 $\mu$ . The band at 0.395 $\mu$  disappears rapidly with dilution. Same empirical formula as solution No. 14.
16. Ponceau 2 R. (A.), (M.) Sodium salt of xylene-azo- $\beta$ -naphthol-disulphonic acid.  
Similar to fig 55, pl. 14; No. 55, S. & J.  
Brownish-red powder. In solution red, pink.  
5 g. per liter (heated).  
Angle 27.3'. Depth 0 to 0.25 mm.  
Hazy-edged band in the blue-green. Similar absorption to that of solution No. 17 in the ultra-violet and identical with it in the visible region.
17. Ponceau 3 R. (A.), (M.) Sodium salt of  $\psi$ -cumene-azo -  $\beta$  - naphthol-disulphonic acid.
17. Ponceau 3 R—*Continued*.  
Fig. 55, pl. 14; No. 56, S. & J.  
Dark-red powder. In solution red, pink. 5 g. per liter (heated).  
Angle 29.3'. Depth 0 to 0.27 mm.  
An absorption band is in the blue-green. It has its maximum at 0.50 $\mu$  and extends from about 0.47 $\mu$  to 0.54 $\mu$ . Transparent from 0.54 $\mu$  to 0.63 $\mu$ .
18. Crystal Ponceau 6 R. (A.), (M.) Sodium salt of  $\alpha$ -naphthalene-azo- $\beta$ -naphthol-disulphonic acid.  
Similar to fig. 55, pl. 14; No. 64, S. & J.  
Brownish-red crystals with golden reflex. In solution light red, pink. 5 g. per liter (heated).  
Angle 27.3'. Depth 0 to 0.25 mm.  
Hazy-edged band in the blue-green and green. Similar absorption to that of solution No. 17. The ultra-violet absorption, however, is somewhat more intense and extends to greater wavelengths for solution No. 18 than for solution No. 17. The visible band extends from 0.465 $\mu$  to 0.56 $\mu$  with its maximum at 0.51 $\mu$ .
19. Bordeaux B. (M.) Sodium salt of  $\alpha$ -naphthalene-azo -  $\beta$  - naphthol-disulphonic acid.  
Similar to fig. 19, pl. 5; No. 65, S. & J.  
Brown powder. In solution red, red. 4.18 g. per liter.  
Angle 42.5'. Depth 0 to 0.36 mm.  
Hazy-edged band in the green. The sides of the band in the green and the orange end of the spectrogram slope a little more for solution No. 19 than for No. 106. Band from 0.485 $\mu$  to 0.545 $\mu$ , with maximum at 0.515 $\mu$ . The least refrangible ends for all the spectrograms slope, thus showing that there is some general absorption in the orange. More concentrated solutions show that the greatest transparency occurs at 0.414 $\mu$ . Same empirical formula as No. 18.
20. Coccine B. (M.) Sodium salt of  $p$ -methoxy-toluene - azo -  $\beta$  - naphthol-disulphonic acid.  
Similar to fig. 55, pl. 14; No. 73, S. & J.  
Dark-red powder. In solution bright-red, red.  
13.64 g. per liter.  
Angle 12.8'. Depth 0 to 0.11 mm.  
Strong absorption in green-yellow. Similar to solution No. 17, save that

20. Coccine B—*Continued*.  
 a weak absorption band seems to have the limits  $0.315\mu$  and  $0.355\mu$ , with a maximum at  $0.33\mu$ . Intense band from  $0.465\mu$  to  $0.555\mu$ , with a maximum at  $0.510\mu$ . Transparent from  $0.555\mu$  to  $0.63\mu$ . Very concentrated solutions or deeper layers show that the transparent region on both sides of  $0.41\mu$  becomes opaque much faster than the orange and red region. Red is transmitted when all shorter wave-lengths are absorbed completely. The solution exhibits strong dispersive power.
21. Eosamine B. (A.) Sodium salt of *p*-cresol - methyl-ether-azo- $\alpha$ -naphthol-disulphonic acid.  
 Fig. 52, pl. 13; No. 74, S. & J.  
 Reddish-brown powder. In solution yellowish red, pink.  
 8.89 g. per liter.  
 Angle  $21.3'$ . Depth 0 to  $0.18$  mm.  
 Strong band in blue-green and green. Intense, round band from  $0.465\mu$  to  $0.565\mu$ , with its maximum at about  $0.52\mu$ . Transparent from  $0.565\mu$  to  $0.63\mu$ . Same empirical formula as No. 20.
22. Erika B. (A.) Sodium salt of methyl-benzenyl - amido - thio-xyleneol-azo- $\alpha$ -naphthol-disulphonic acid.  
 Fig. 57, pl. 15; No. 78, S. & J.  
 Reddish-brown powder. In solution red, pink.  
 6.67 g. per liter.  
 Angle  $19.5'$ . Depth 0 to  $0.18$  mm.  
 Strong absorption in blue, green, and green-yellow. Two unresolved bands absorb strongly from  $0.46\mu$  to  $0.59\mu$ . The more refrangible band shows greater intensity than its companion and has its maximum at  $0.52\mu$ . Slight absorption in the orange is followed by greater transparency in the red.
23. Emin Red. (A.) Sodium salt of methyl-benzenyl - amido - thioxyleneol-azo- $\beta$ -naphthol-sulphonic acid.  
 Fig. 29, pl. 8; No. 80, S. & J.  
 Red powder. In solution red, pink.  
 Saturated (heated).  
 Angle  $31.2'$ . Depth 0 to  $0.29$  mm.  
 Weak, hazy absorption in blue and green. Strong absorption from  $0.20\mu$  to about  $0.35\mu$ , then a rather rapid decrease in absorption sets in. From
23. Emin Red—*Continued*.  
 $0.38\mu$  to  $0.45\mu$  a semi-transparent region exists. A round band extends from  $0.45\mu$  to  $0.54\mu$ . Its maximum is near  $0.495\mu$ . The less refrangible side of this band is far more definite than its ultra-violet edge. Transparent from  $0.54\mu$  to  $0.63\mu$ .
24. Janus Green. (M.) Chloride of safranine-azo-dimethylaniline.  
 No. 81, S. & J.  
 Olive-green, crystalline powder. In solution blue, blue.  
 4.6 g. per liter.  
 Angle  $17.0'$ . Depth 0 to  $0.14$  mm.  
 Band in orange and orange-red. Transparent to pure red. Very general absorption in ultra-violet, decreasing gradually from  $0.20\mu$  to  $0.40\mu$ . Transparent from  $0.40\mu$  to  $0.515\mu$ . The absorption band begins at  $0.515\mu$ .
25. Tropæoline O. (C.) Sodium salt of *p*-sulphobenzene-azo-resorcinol.  
 Similar to fig. 37, pl. 10; No. 84, S. & J.  
 Brown powder. In solution wine-color, yellow.  
 Saturated (heated).  
 Angle  $25.5'$ . Depth 0 to  $0.21$  mm.  
 Faint absorption in the violet. Similar absorption to that of solution No. 81. Weak absorption from  $0.20\mu$  to  $0.275\mu$ . Transparent from  $0.275\mu$  to  $0.325\mu$ . A weak, hazy band extends from  $0.325\mu$  to  $0.41\mu$  with its maximum around  $0.37\mu$ . Transparent from  $0.41\mu$  to  $0.63\mu$ .
26. Tropæoline OOO No. 1. Sodium salt of *p*-sulphobenzene-azo- $\alpha$ -naphthol.  
 Similar to fig. 31, pl. 8; No. 85, S. & J.  
 Reddish-brown powder. In solution red, salmon pink.  
 6.67 g. per liter.  
 Angle  $21.3'$ . Depth 0 to  $0.18$  mm.  
 Absorption in violet, blue, and green. Similar absorption to that of solution No. 15. Rather strong absorption continues from  $0.20\mu$  to about  $0.33\mu$  and then decreases rapidly to semi-transparency. A tolerably transparent region is from  $0.35\mu$  to  $0.37\mu$ . Three unresolved bands with maxima at about  $0.41\mu$ ,  $0.48\mu$ , and  $0.52\mu$  follow. The intermediate points of less intensity of absorption are  $0.435\mu$  and  $0.450\mu$ . At  $0.545\mu$  the absorption ceases. Transparent from  $0.545\mu$  to  $0.63\mu$ .



27. Tropæoline OOO No. 2. Sodium salt of *p*-sulphobenzene-azo- $\beta$ -naphthol. No. 86, S. & J. Bright, orange powder. In solution deep red, salmon pink. 1.4 g. per liter. Angle 21.3'. Depth 0 to 0.18 mm. Visible absorption and spectrogram identical with No. 26. Similar absorption to that of solution No. 15. Nos. 26 and 27 have the same empirical formulae, but differ by  $\alpha$  and  $\beta$  in the naphthol.
28. Methyl Orange III. (P.) Sodium salt of *p*-sulphobenzene-azo-dimethylaniline. Fig. 41, pl. 11; No. 87, S. & J. Ocher-yellow powder. In solution red, yellow. Saturated (heated). Angle 27.3'. Depth 0 to 0.25 mm. Absorption in blue and green. A strong band extends from 0.36 $\mu$  to 0.525 $\mu$ . This band is very round with its maximum at 0.44 $\mu$ . Transparent from 0.525 $\mu$  to 0.63 $\mu$ .
29. Tropæoline OO. (C.) Sodium salt of *p*-sulphobenzene-azo-diphenylamine. Similar to fig. 40, pl. 10; No. 88, S. & J. Yellow powder. In solution yellowish red, yellow. 6 g. per liter (heated and filtered). Angle 25.5'. Depth 0 to 0.21 mm. Delicate absorption in violet and blue. Similar absorption to that of solution No. 32. The extreme ultraviolet absorption is weak because the lines near 0.23 $\mu$  show on all three photographic strips. From 0.385 $\mu$  to 0.47 $\mu$  a weak absorption band obtains with its maximum at 0.43 $\mu$ . The substance is very transparent to yellow and red. Nos. 29 and 32 have the same empirical formulae. No. 29 is the para-compound and No. 32 is the meta-. No. 29 shows weaker absorption than No. 32.
30. Curcumeine. (A.) Mixture of nitrated diphenylamine yellow with nitrodiphenylamine. Fig. 12, pl. 3; No. 91, S. & J. Ocher-yellow powder. In solution red, yellow. Saturated (heated). Angle 27.3'. Depth 0 to 0.25 mm.
30. Curcumeine—*Continued*. Absorption in violet, blue, and blue-green. Absorption complete at 0.20 $\mu$ , decreasing very gradually with comparatively definite contour to 0.455 $\mu$ . Transparent from 0.455 $\mu$  to 0.63 $\mu$ .
31. Azo Acid Yellow. (A.) Azo Yellow, concentrated. (M.) Mixture of nitrated diphenylamine yellow with nitro-diphenylamine. Similar to fig. 12, pl. 3; No. 92, S. & J. Ocher-yellow powder. In solution brownish yellow, yellow. Saturated (heated). Angle 27.3'. Depth 0 to 0.25 mm. Strong absorption of violet, blue, and blue-green. Similar absorption to that of solution No. 30. Absorption is nearly complete and uniform from 0.20 $\mu$  to about 0.39 $\mu$ . Then the absorption decreases in a gently sloping curve to about 0.505 $\mu$ . Transparent to yellow and red. Nos. 30 and 31 are mixtures of the same constituents and have very similar regions of absorption.
32. Metanil Yellow. (A.) Sodium salt of *m*-sulphobenzene-azo-diphenylamine. Fig. 40, pl. 10; No. 95, S. & J. Brownish-yellow powder. In solution yellowish red, yellow. 4.29 g. per liter (filtered). Angle 23.4'. Depth 0 to 0.21 mm. Absorption in violet and blue. A band with very indefinite boundary extends from about 0.36 $\mu$  to 0.47 $\mu$ . The maximum is near 0.41 $\mu$ . Transparent to yellow and red. A very concentrated solution shows complete absorption from 0.20 $\mu$  to 0.51 $\mu$  with a semi-transparent spot at 0.34 $\mu$  and maximum absorption at 0.40 $\mu$ . Absorption ceases abruptly at 0.535 $\mu$ .
33. Naphthylamine Brown. Sodium salt of *p*-sulphonaphthalene-azo- $\alpha$ -naphthol. Similar to fig. 11, pl. 3; No. 101, S. & J. Brown powder. In solution reddish brown, almost colorless. 11.11 g. per liter (heated and filtered). Angle 30.0'. Depth 0 to 0.45 mm. Very weak, general, indefinite absorption for all visible colors of shorter wave-lengths than the yellow. Similar absorption to that of solution No. 47. Absorption was nearly complete from 0.20 $\mu$  to 0.274 $\mu$ . From

33. Naphthylamine Brown—*Continued.*  
the latter wave-length the absorption decreased very gradually to a maximum of semi-transparency at about  $0.43\mu$ . The apparent absorption at  $0.52\mu$  is much exaggerated by the lack of relative sensitiveness of the photographic film at this spot. Very slight absorption from  $0.55\mu$  to  $0.63\mu$ . A weaker solution presented only ultra-violet absorption.
34. Fast Red A. (A.) New Coccine O. (M.) Sodium salt of *p*-sulphonaphthalene-azo- $\beta$ -naphthol.  
Fig. 27, pl. 7; No. 102, S. & J.  
Brownish-red powder. In solution red, pink.  
5 g. per liter (heated).  
Angle  $27.3'$ . Depth 0 to 0.25 mm.  
Hazy absorption in blue-green and general absorption in blue. Muddy-looking solution. Two partially resolved bands extend from  $0.415\mu$  to  $0.54\mu$  with maxima of absorption at about  $0.45\mu$  and  $0.505\mu$ . The less refrangible band is the more intense. Orange and red are transmitted, but the sloping end of the photograph shows that slight, general absorption is present in orange. Nos. 33 and 34 have the same empirical formulæ. They differ by  $\alpha$  and  $\beta$  naphthol.
35. Azo Rubine S. (A.) Sodium salt of *p*-sulphonaphthalene-azo- $\alpha$ -naphthol-*p*-sulphonic acid.  
Similar to fig. 55, pl. 14; No. 103, S. & J.  
Brown powder. In solution red, pink.  
10 g. per liter.  
Angle  $19.5'$ . Depth 0 to 0.18 mm.  
Absorption in green. Much like solution No. 17 with slight differences in the ultra-violet. Absorption decreases from  $0.20\mu$  to  $0.27\mu$ . The strong lines at  $0.255\mu$  and  $0.275\mu$  are transmitted by the deepest layer. Absorption increases from  $0.27\mu$  to a maximum at  $0.315\mu$ . Then the absorption decreases to approximate transparency at  $0.36\mu$ . Transparent from  $0.36\mu$  to  $0.465\mu$ . Strong band from  $0.465\mu$  to  $0.555\mu$  with maximum at  $0.51\mu$ . The visible band is in the same place as the like band of No. 20, but the ultra-violet is different. Transparent to orange and red.
36. Fast Red, extra. (A.) Sodium salt of *p*-sulphonaphthalene-azo- $\beta$ -naphthol-monosulphonic acid.  
Similar to fig. 55, pl. 14; No. 105, S. & J.  
Reddish-brown powder. In solution red, pink.  
7 g. per liter.  
Angle  $27.3'$ . Depth 0 to 0.25 mm.  
Absorption in blue-green and green. Absorption the same throughout as for No. 35 except the position of the visible band. No. 36 absorbs from  $0.460\mu$  to  $0.545\mu$  with the maximum at  $0.505\mu$ . Same empirical formula as for No. 35.
37. New Coccine. (A.) Sodium salt of *p*-sulphonaphthalene-azo- $\beta$ -naphthol-disulphonic acid.  
Similar to fig. 52, pl. 13; No. 106, S. & J.  
Scarlet-red powder. In solution yellowish red, pink.  
10 g. per liter.  
Angle  $23.4'$ . Depth 0 to 0.21 mm.  
Absorption in blue-green and green. Similar absorption to that of solution No. 21. The ultra-violet absorption of solution No. 37 seems to consist only of one band whereas that of solution No. 21 seems to be separated into two bands by a minimum of absorption near  $0.274\mu$ . Absorption decreases from  $0.20\mu$  to transparency about  $0.37\mu$ . A strong, round band from  $0.445\mu$  to  $0.56\mu$  has its maximum at  $0.51\mu$ . Transparent from  $0.56\mu$  to  $0.63\mu$ .
38. Fast Brown 3 B. (A.) Sodium salt of sulphonaphthalene-azo- $\alpha$ -naphthol.  
Similar to fig. 23, pl. 6; No. 111, S. & J.  
Dark-brown, glistening powder. In solution reddish brown, faint brown.  
15 g. per liter.  
Angle  $27.3'$ . Depth 0 to 0.25 mm.  
Absorption most intense in blue-green and green with slight general absorption on both sides. Similar absorption to that of solution No. 60. A fairly strong band from  $0.46\mu$  to  $0.54\mu$  has its maximum at  $0.51\mu$ . No definite band from  $0.54\mu$  to  $0.63\mu$ , but general absorption is made evident by the slope of the end of the negative.

39. Mordant Yellow O. (M.) Sodium salt of sulphonaphthalene-azo-salicylic acid. Similar to fig. 13, pl. 3; No. 116, S. & J. Yellow powder. In solution reddish yellow, yellow.  
10 g. per liter.  
Angle  $31.2'$ . Depth 0 to 0.29 mm.  
Absorption in the violet only. Similar absorption to that of solution No. 129. Strong absorption from  $0.20\mu$  to  $0.28\mu$ . Slight weakening of absorption from  $0.28\mu$  to  $0.34\mu$ . Absorption attains a maximum at  $0.36\mu$  and then slopes gradually, with a comparatively definite edge, to transparency at  $0.44\mu$ . From this point to  $0.63\mu$  complete transparency exists.
40. Dianil Yellow R. (M.)  
Similar to fig. 37, pl. 10; No. 124, S. & J.  
Orange-yellow powder. In solution clear yellow, yellow.  
Saturated.  
Angle  $31.2'$ . Depth 0 to 0.29 mm.  
Faint absorption in violet. Similar absorption to that of solution No. 81. Absorption is comparatively strong at  $0.20\mu$  and decreases to partial transparency near  $0.295\mu$ . A tolerably weak band extends from this region to about  $0.435\mu$ . Its maximum is indeterminate. Transparent from  $0.44\mu$  to  $0.63\mu$ .
41. Resorcine Brown. (A.) Sodium salt of xylene-azo-resorcin-azo-benzene-*p*-sulphonic acid.  
Fig. 38, pl. 10; No. 137, S. & J.  
Brown powder. In solution brown, yellow.  
7.78 g. per liter.  
Angle  $23.4'$ . Depth 0 to 0.21 mm.  
Strong absorption in the violet and blue. A more concentrated solution exhibited absorption in the green and yellow. A long band or region of absorption extends from  $0.35\mu$  to  $0.52\mu$ . The maximum is near  $0.395\mu$ . There is a slight minimum of absorption at  $0.48\mu$ . The presence of a weaker, less refrangible band, increasing in intensity at  $0.48\mu$ , is more marked as the concentration is increased. More concentrated solutions show that the transparency in the ultra-violet rapidly disappears,
41. Resorcine Brown—*Continued*.  
whereas the bands do not encroach as rapidly on the yellow. Transparent from  $0.53\mu$  to  $0.63\mu$ . The absorption of the concentrated solutions is like that of solution No. 77, fig. 35.
42. Acid Brown. (D.) Sodium salt of bisulphobenzene-disazo-*a*-naphthol.  
Similar to fig. 39, pl. 10; No. 138, S. & J.  
Brown powder. In solution brown, yellow.  
7.5 g. per liter.  
Angle  $25.5'$ . Depth 0 to 0.21 mm.  
Absorption in violet and blue. Similar absorption to that of solution No. 8. Very weak absorption from  $0.20\mu$  to  $0.29\mu$ . Transparent to continuous background of spark from  $0.29\mu$  to  $0.33\mu$ . Weak, indefinite absorption band from  $0.33\mu$  to  $0.48\mu$ , with maximum indeterminate. Transparent to yellow, orange, and red.
43. Ponceau B O, extra. (A.) Sodium salt of benzene-azo-benzene-azo- $\beta$ -naphthol-disulphonic acid.  
Similar to fig. 52, pl. 13; No. 146, S. & J.  
Light-brown powder. In solution yellowish red, pink.  
7 g. per liter.  
Angle  $21.5'$ . Depth 0 to 0.20 mm.  
Strong absorption in blue and green. Similar absorption to that of solution No. 21. Absorption decreases from  $0.20\mu$  to  $0.295\mu$ , and then increases to a maximum near  $0.345\mu$ . This band fades to semi-transparency about  $0.4\mu$ . The width and general appearance of the region of separation between the ultra-violet bands and the band in the green resembles much more closely the corresponding region for solution No. 48 than for solution No. 21. Transparency continues from  $0.4\mu$  to  $0.44\mu$ , where a strong, round band begins. The last band ends at  $0.565\mu$ . Its maximum is at  $0.51\mu$ . Transparent from  $0.565\mu$  to  $0.63\mu$ . Absorption from this band moves more rapidly towards the ultra-violet than towards the red, with increasing concentration. Same empirical formula as No. 42.

44. Janus Red B. (M.) Chloride of trimethyl-amido-benzene-azo-*m*-toluene-azo- $\beta$ -naphthol.  
Similar to fig. 23, pl. 6; No. 149, S. & J.  
Reddish-brown powder. In solution yellowish red, faint yellowish red. Saturated.  
Angle  $54.6'$ . Depth 0 to 0.50 mm.  
Pointed, V-shaped, weak band in the blue-green. Similar absorption to that of solution No. 60. Absorption is strong at  $0.20\mu$  and decreases gradually and in a poorly defined manner to transparency at  $0.375\mu$ . The transparent region continues to  $0.455\mu$ . An absorption band lies between  $0.455\mu$  and  $0.540\mu$ , with its maximum at  $0.51\mu$ . Slight general absorption in the yellow and orange, but transparent to the red.
45. Cloth Red G. (O.) Sodium salt of toluene-azo-toluene-azo- $\beta$ -naphthol-monosulphonic acid.  
Fig. 25, pl. 7; No. 153, S. & J.  
Reddish-brown powder. In solution red, faint pink.  
8.33 g. per liter (heated and filtered).  
Angle  $31.2'$ . Depth 0 to 0.29 mm.  
Bands in blue-green and green with hazy edges and weak general absorption in both directions. A band extends from  $0.445\mu$  to  $0.55\mu$  and appears to be composed of a stronger band with a weaker, more refrangible, unresolved companion. Their maximum of absorption is at  $0.515\mu$ . The slant at the end of the negative shows that weak, general absorption is exerted in the orange. Transparent to the red.
46. Cloth Red O. (M.) Sodium salt of toluene-azo-toluene-azo- $\beta$ -naphthol-disulphonic acid.  
Fig. 21, pl. 6; No. 154, S. & J.  
Dark-brown powder. In solution deep red, very faint red.  
6.36 g. per liter (warmed and filtered).  
Angle  $33.2'$ . Depth 0 to 0.30 mm.  
Maximum of absorption in blue-green with weak absorption in yellow and orange. Absorption band starts at  $0.485\mu$ , attains its maximum at  $0.52\mu$ , and is dissipated in weak general absorption about  $0.555\mu$ . The end of the negative slants appreciably. Transparent to red.
47. Cloth Red 3 G A. (A.) Sodium salt of toluene-azo-toluene-azo- $\beta$ -naphthylamine-monosulphonic acid.  
Fig. 11, pl. 3; No. 155, S. & J.  
Brownish-red powder. In solution reddish brown, light brown. Saturated (heated).  
Angle  $1^\circ 57'$ . Depth 0 to 1.07 mm.  
General absorption in violet, also a maximum of absorption in the blue-green and green. Absorption is about complete at  $0.20\mu$  and increases very gradually, with hazy contour, to semi-transparency at about  $0.42\mu$ . Semi-transparency from  $0.42\mu$  to  $0.49\mu$ . Weak band from  $0.49\mu$  to  $0.54\mu$ . Transparent from  $0.54\mu$  to  $0.63\mu$ .
48. Poncean 4 R B. (A.) Sodium salt of sulphobenzene-azo-benzene-azo- $\beta$ -naphthol-monosulphonic acid.  
Fig. 51, pl. 13; No. 160, S. & J.  
Reddish-brown powder. In solution yellowish red, pink.  
10 g. per liter (heated).  
Angle  $19.5'$ . Depth 0 to 0.18 mm.  
Strong absorption in blue-green and green. At  $0.455\mu$  the strong band begins and extends to  $0.565\mu$ , with its maximum about  $0.51\mu$ . Transparent from  $0.565\mu$  to  $0.63\mu$ .
49. Biebrich Scarlet. (K.) Sodium salt of sulphobenzene-azo-sulphobenzene-azo- $\beta$ -naphthol.  
Similar to fig. 51, pl. 13; No. 163, S. & J.  
Reddish-brown powder. In solution red, pink.  
6 g. per liter.  
Angle  $19.5'$ . Depth 0 to 0.18 mm.  
Absorption band in blue-green and green. Absorption decreases from  $0.20\mu$  to about  $0.32\mu$ , where a semi-transparent region appears. This is followed by an absorption band with its maximum at  $0.355\mu$ . Slight absorption from  $0.39\mu$  to  $0.45\mu$ . A definite band starts at  $0.45\mu$ , reaches a maximum near  $0.51\mu$ , and ends at  $0.555\mu$ . Transparent from  $0.555\mu$  to  $0.63\mu$ . A solution of 10 g. per liter showed almost complete absorption from  $0.20\mu$  to  $0.36\mu$ . From  $0.395\mu$  to  $0.445\mu$  only the first photographic strip received light. The band is very round from  $0.445\mu$  to its end at

49. Biebrich Scarlet—*Continued*.  
 0.585 $\mu$ . Transparent to orange and red. Same empirical formula as No. 48 and almost identical visible absorption.
50. Wool Black. (A.) Sodium salt of sulphobenzene-azo-sulphobenzene-azo-*p*-tolyl- $\beta$ -naphthylamine.  
 Fig. 67, pl. 17; No. 166, S. & J.  
 Bluish-black powder. In solution purple, light purple.  
 5.56 g. per liter (filtered).  
 Angle 35.1'. Depth 0 to 0.32 mm.  
 Hazy band in yellow spreading indefinitely into the orange. Transmits bright red. At 0.49 $\mu$  a region of absorption commences which seems to consist of a hazy central band with a weak, washed-out companion on each side. The chief maximum is about 0.54 $\mu$ . Absorption is very weak from 0.60 $\mu$  to 0.63 $\mu$ . A very concentrated solution shows that the maximum of transparency is near 0.44 $\mu$ .
51. Ponceau 6 R B. (A.) Sodium salt of sulphotoluene-azo-toluene-azo- $\beta$ -naphthol-*a*-sulphonic acid.  
 Fig. 56, pl. 14; No. 169, S. & J.  
 Reddish-brown powder. In solution scarlet red, pink.  
 5.38 g. per liter.  
 Angle 31.2'. Depth 0 to 0.29 mm.  
 Strong band in the green which is more definite on the blue side than on the yellow border. Strong band from 0.465 $\mu$  to 0.565 $\mu$ . The maximum is at 0.51 $\mu$ . The band is probably composed of two unresolved bands of which the weaker lies nearer the red. Transparent from 0.565 $\mu$  to 0.63 $\mu$ .
52. Blue-Black. (B.) Sodium salt of sulpho- $\beta$ -naphthalene-azo-*a*-naphthalene-azo- $\beta$ -naphthol-disulphonic acid.  
 No. 186, S. & J.\*  
 Bluish-black powder. In solution bluish violet, violet.  
 6.69 g. per liter (filtered).  
 Angle 33.2'. Depth 0 to 0.30 mm.  
 Very indefinite absorption in green-yellow, yellow, and orange, with maximum in yellow. Absorption is strong at 0.20 $\mu$  and decreases gradually to about 0.34 $\mu$ . Approximately transparent from 0.4 $\mu$  to 0.5 $\mu$ . Absorption starts near 0.50 $\mu$ , increases to a maximum about 0.54 $\mu$ , and de-
52. Blue-Black—*Continued*.  
 creases to weak, general absorption from 0.58 $\mu$  to 0.63 $\mu$ .
53. Anthracene Yellow C. (C.) Sodium salt of thio-di-benzene-disazo-di-salicylic acid.  
 Similar to fig. 37, pl. 10; No. 190, S. & J.  
 Brownish-yellow powder. In solution muddy yellowish brown, greenish yellow.  
 6 g. per liter (filtered).  
 Angle 21.3'. Depth 0 to 0.18 mm.  
 Absorption in violet. Somewhat similar absorption to that of solution No. 81. However, the absorption of solution No. 53 is more intense than that of solution No. 81. Absorption decreases from 0.20 $\mu$  to a semi-transparent strip at about 0.295 $\mu$ . Beyond this strip a band with hazy contour extends as far as 0.41 $\mu$  with its maximum at about 0.34 $\mu$ . Transparent from 0.41 $\mu$  to 0.63 $\mu$ .
54. Bismarck Brown. (A.) Hydrochloride of benzene-disazo-phenylene-diamine.  
 Fig. 7, pl. 2; No. 197, S. & J.  
 Dark-brown powder. In solution brown, yellow.  
 30 g. per liter (filtered).  
 Angle 19.5'. Depth 0 to 0.18 mm.  
 Visible and photographic absorption identical with that of solution No. 12.
55. Vesuvine. (B.) Hydrochloride of toluene-disazo-*m*-tolylene-diamine.  
 Fig. 7, pl. 2; No. 201, S. & J.  
 Dark-brown powder. In solution reddish brown, yellow.  
 4.29 g. per liter.  
 Angle 31.2'. Depth 0 to 0.29 mm.  
 Visible and photographic absorption identical with that of solution No. 12.
56. Congo Orange G. (A.) Sodium salt of diphenyl-disazo-phenetol- $\beta$ -naphthylamine-disulphonic acid.  
 Fig. 33, pl. 9; No. 217, S. & J.  
 Brownish-red powder. In solution reddish yellow, yellow.  
 5.38 g. per liter.  
 Angle 23.4'. Depth 0 to 0.21 mm.  
 Hazy absorption in blue, blue-green, and green with maximum in the green. Tolerably strong absorption decreases from 0.20 $\mu$  to a weak minimum near 0.32 $\mu$  and then increases to a maximum about 0.36 $\mu$ . A semi-transparent region lies between

\* Spectrogram too indefinite for reproduction.

56. Congo Orange G—*Continued*.  
 0.405 $\mu$  and 0.44 $\mu$ . A weak, hazy band begins at 0.44 $\mu$  and continues to 0.475 $\mu$ , at which point it joins a more intense band. The latter has its maximum at 0.505 $\mu$  and then decreases to transparency at 0.53 $\mu$ . Transparent from 0.53 $\mu$  to 0.63 $\mu$ . More concentrated solutions emphasize all the maxima of absorption just outlined and the minimum at 0.42 $\mu$ .
57. Chrysamine G. (A.) Sodium salt of diphenyl-disazo-bi-salicylic acid. Similar to fig. 36, pl. 9; No. 220, S. & J. Yellowish-brown powder. In solution brownish yellow, faint yellow. 7 g. per liter (heated and filtered). Angle 35.1'. Depth 0.26 to 0.58 mm. No visible absorption unless, perhaps, a faint weakening of the extreme violet. Somewhat similar absorption to that of the more dilute solution of No. 77. For the layer used the absorption is nearly complete from 0.20 $\mu$  to 0.29 $\mu$ . The continuous background is transmitted from 0.29 $\mu$  to 0.30 $\mu$ . The limit of the ultra-violet absorption is approximately a straight line joining the wave-lengths 0.365 $\mu$  and 0.395 $\mu$  at the opposite edges of the negative. Transparent from 0.395 $\mu$  to 0.63 $\mu$ . More dilute solutions and wedges of liquid tapering to infinitesimal thickness show that ultra-violet absorption is very weak.
58. Cresotine Yellow G. (M.) Sodium salt of diphenyl-disazo-bi-*o*-cresol-carboxylic acid. Similar to fig. 36, pl. 9; No. 221, S. & J. Yellowish-brown powder. In solution yellow, faint yellow. Saturated. Angle 39.0'. Depth 0 to 0.36 mm. Absorption in violet and indigo. Absorption much like that of the more dilute solution of No. 77. The solution has a peculiar odor. A washed-out band begins at 0.31 $\mu$ , passes through a maximum near 0.355 $\mu$ , and then fades away at 0.44 $\mu$ . A rather narrow region of semi-transparency, the center of which is near 0.30 $\mu$ , separates this band from a weak, more refrangible ultra-violet band. Transparent from 0.44 $\mu$  to 0.63 $\mu$ .
59. Congo Red. (A.) Sodium salt of diphenyl-disazo-bi-naphthionic acid. Similar to fig. 26, pl. 7; No. 240, S. & J. Reddish-brown powder. In solution red, yellowish red. 5.9 g. per liter. Angle 27.3'. Depth 0 to 0.25 mm. Absorption in blue, blue-green, and green with maximum nearer the green end. Similar absorption to that of solution No. 69. Absorption decreases from 0.20 $\mu$  to near 0.28 $\mu$  and then increases to a maximum at about 0.325 $\mu$ . These two partially resolved bands are followed by a region of approximate transparency extending from 0.385 $\mu$  to 0.426 $\mu$  with its maximum at 0.405 $\mu$ . Transparency is terminated at 0.426 $\mu$  by a pair of wide, hazy bands of which the more refrangible is the weaker. The chief maximum is at 0.505 $\mu$ . Absorption ends at 0.545 $\mu$ . Transparent from 0.545 $\mu$  to 0.63 $\mu$ . More concentrated solutions show that the ultra-violet and visible bands soon run together, whereas the absorption does not advance much towards the orange.
60. Congo Corinth G. (A.) Sodium salt of diphenyl-disazo-naphthionic- $\alpha$ -naphthol-sulphonic acid. Fig. 23, pl. 6; No. 242, S. & J. Greenish-black powder. In solution brownish red, red. 5.38 g. per liter (heated). Angle 27.3'. Depth 0 to 0.25 mm. Absorption in blue-green, green, and yellow. Very general absorption at the red border. Absorption band from 0.46 $\mu$  to 0.555 $\mu$  with its maximum near 0.515 $\mu$ . The end of the negative slants considerably, showing that general absorption continues into the orange. Transparent to red. Same empirical formula as No. 61, but different constitution.
61. Congo Rubine. (A.) Sodium salt of diphenyl-disazo-naphthionic acid- $\beta$ -naphthol-sulphonic acid. Similar to fig. 19, pl. 5; No. 243, S. & J. Greenish, crystalline powder. In solution bluish red, dull red. Saturated (warmed). Angle 39.0'. Depth 0.26 to 0.62 mm.

61. Congo Rubine—*Continued*.

Absorption in blue-green. Absorption, especially in the visible spectrum, similar to that of solution No. 106. A layer about 2 mm. deep absorbs all the visible spectrum except the orange and red. Complete absorption at  $0.20\mu$  decreases to a minimum near  $0.275\mu$ , then increases to a maximum at about  $0.31\mu$ , and finally vanishes in transparency at  $0.345\mu$ . Absorption band from  $0.485\mu$  to  $0.55\mu$  with its maximum at  $0.52\mu$ . Transparent from  $0.55\mu$  to  $0.63\mu$ . Same empirical formula as No. 60, but different constitution.

62. Anthracene Red. (I.) Sodium salt of nitrodiphenyl - disazo - salicylic- $\alpha$ -naphthol-sulphonic acid.

Similar to fig. 56, pl. 14; No. 262, S. & J.

Brownish-red powder. In solution deep red, pink.

7.5 g. per liter.

Angle  $27.3'$ . Depth 0 to 0.25 mm.

Hazy-edged band in the blue-green and green. Similar absorption to that of solution No. 51. Absorption decreases from  $0.20\mu$  to semi-transparency at  $0.29\mu$ . About  $0.31\mu$  a well-rounded, hazy-edged band starts, passes through its maximum near  $0.36\mu$ , and ceases at  $0.42\mu$ . Partial transparency from  $0.42\mu$  to  $0.465\mu$ . A symmetrical absorption band prevents transmission from  $0.465\mu$  to  $0.55\mu$ . Its maximum is near  $0.51\mu$ . Transparent from  $0.55\mu$  to  $0.63\mu$ . Less concentrated solutions show that the ultra-violet absorption is comparatively weak.

63. Congo Orange R. (A.) Sodium salt of ditolyl - disazo - phenetol- $\beta$ -naphthylamine-disulphonic acid.

Similar to fig. 11, pl. 3; No. 275, S. & J. Yellowish-red powder. In solution brown, yellowish brown.

5 g. per liter (warmed and filtered).

Angle  $39.0'$ . Depth 0 to 0.36 mm.

Indefinite, general absorption in the blue and blue-green. The liquid is not clear, but behaves somewhat like an emulsion. Similar absorption to that of solution No. 47. Absorption decreases from  $0.20\mu$  to about  $0.29\mu$  and then remains about constant as far as  $0.365\mu$ . From this point it de-

63. Congo Orange R—*Continued*.

creases to very weak, general absorption at  $0.43\mu$ . A slight increase in absorption has its maximum at  $0.515\mu$ . It is partly, but not entirely, due to the weak spot of the Seed emulsion. Transparent from  $0.54\mu$  to  $0.63\mu$ . Deeper layers of greater concentration show the minimum of absorption to be the region around  $0.455\mu$ .

64. Benzopurpurine 6 B. (A.) Sodium salt of ditolyl - disazo - bi- $\alpha$ -naphthylamine-sulphonic acid.

Similar to fig. 26, pl. 7; No. 278, S. & J. Red powder. In solution red, brownish red.

7.78 g. per liter (filtered).

Angle  $29.3'$ . Depth 0 to 0.27 mm.

Hazy-edged band in blue and green. Similar absorption to that of solution No. 69. Strong absorption from  $0.415\mu$  to  $0.55\mu$ . The chief maximum of absorption is at  $0.51\mu$ . Probably two hazy, unresolved bands, with more refrangible, weaker component. Transparent from  $0.55\mu$  to  $0.63\mu$ . Weaker solutions show more rapid increase of transparency on the ultra-violet side of the visible band than on the red side.

65. Benzopurpurine B. (A.) Sodium salt of ditolyl-disazo-bi- $\beta$ -naphthylamine- $\beta$ -sulphonic acid.

Similar to fig. 26, pl. 7; No. 279, S. & J. Brown powder. In solution reddish brown, brown.

8.75 g. per liter.

Angle  $25.4'$ . Depth 0 to 0.23 mm.

Same visible and photographic absorption as No. 69. Identical visible absorption to that of solution No. 64. Solutions Nos. 65 and 69 seem to have only one region of absorption in the ultra-violet, whereas solution No. 64 has a slight minimum of absorption near  $0.275\mu$ . Nos. 64 and 65 have the same empirical formulæ, but different chemical constitution.

66. Diamine Red B. (A.) Deltapurpurine 5 B. (M.) Sodium salt of ditolyl-disazo-bi- $\beta$ -naphthylamine-sulphonic acid.

Similar to fig. 26, pl. 7; No. 280, S. & J. Reddish-brown powder. In solution yellowish red, pink.

66. Diamine Red B—*Continued*.  
6.36 g. per liter (warmed and filtered).  
Angle 25.4'. Depth 0 to 0.23 mm.  
Same visible absorption as No. 64.  
Similar absorption to that of solution No. 69. Nos. 64 and 66 have the same empirical formulæ, but different chemical constitutions.
67. Brilliant Congo R. (A.) Sodium salt of ditolyl-disazo- $\beta$ -naphthylamine-monosulphonic- $\beta$ -naphthylamine-disulphonic acid.  
Similar to fig. 26, pl. 7; No. 281, S. & J. Brown powder. In solution, yellowish red, yellowish red.  
8 g. per liter.  
Angle 31.2'. Depth 0 to 0.29 mm.  
Hazy-edged band in blue and green.  
Similar absorption to that of solution No. 69. A pair of unresolved bands extends from 0.42 $\mu$  to 0.56 $\mu$ , with their chief maximum at 0.515 $\mu$ . The less refrangible band is the more intense. Transparent from 0.555 $\mu$  to 0.63 $\mu$ .
68. Diamine Red 3 B. (A.) Sodium salt of ditolyl-disazo-bi- $\beta$ -naphthylamine- $\delta$ -sulphonic acid.  
Fig. 61, pl. 16; No. 282, S. & J.  
Reddish-brown powder. In solution reddish brown, brown.  
7 g. per liter (heated and filtered).  
Angle 50.7'. Depth 0.64 mm. to 1.10 mm.  
Hazy-edged absorption in the blue-green and green. A pair of unresolved bands absorbs from about 0.435 $\mu$  to 0.545 $\mu$ . Their maximum is near 0.515 $\mu$ . The more refrangible band is weaker and more indefinite than its companion. Transparent from 0.545 $\mu$  to 0.63 $\mu$ .
69. Brilliant Purpurine R.—*Continued*.  
solved bands absorbs all radiations between 0.411 $\mu$  and 0.563 $\mu$ . The less refrangible band is the more intense and has its maximum at 0.515 $\mu$ . Transparent from 0.563 $\mu$  to 0.63 $\mu$ .
70. Rosazurine B. (B.) Sodium salt of ditolyl-disazo-bi-ethyl- $\beta$ -naphthylamine-sulphonic acid.  
Similar to fig. 26, pl. 7; No. 285, S. & J. Brown powder. In solution red, pink. 7 g. per liter (heated).  
Angle 27.3'. Depth 0 to 0.25 mm.  
Weak absorption in the green, with very hazy, blue boundary. Similar absorption to that of solution No. 69. The precise size and shape of the visible band matches very closely the corresponding band of solution No. 45, fig. 25. Absorption from 0.47 $\mu$  to 0.55 $\mu$ , with the maximum near 0.515 $\mu$ . Transparent from 0.55 $\mu$  to 0.63 $\mu$ .
71. Congo Corinth. Sodium salt of ditolyl-disazo-naphthionic- $\alpha$ -naphthol- $p$ -sulphonic acid.  
Similar to fig. 22, pl. 6; No. 286, S. & J. Grayish-black powder. In solution red, pink.  
9.09 g. per liter (very gritty; filtered often).  
Angle 21.5'. Depth 0 to 0.20 mm.  
General absorption in green, yellow, and orange. Very weak and hazy towards the red. Similar absorption to that of solution No. 74. Weak, general absorption in ultra-violet, permitting all strong lines to pass through the solution. It fades away about 0.35 $\mu$ . Several plates and films show that absorption begins again about 0.49 $\mu$  and becomes relatively small at 0.56 $\mu$ . Weak, general absorption, however, continues to 0.63 $\mu$ . The maximum of absorption is indeterminate. Saturated solutions gave the same general results.
72. Azo Blue. (By.) Sodium salt of ditolyl-disazo-bi- $\alpha$ -naphthol- $p$ -sulphonic acid. Somewhat like fig. 22, pl. 6; No. 287, S. & J.  
Bluish-black powder. In solution deep blue, reddish blue.  
4.29 g. per liter.  
Angle 23.4'. Depth 0 to 0.21 mm.  
Hazy-edged absorption in green-yellow, yellow, and orange. The red border



72. Azo Blue—*Continued.*

is very indefinite and the maximum appears to be in the yellow. Absorption is like that of solution No. 74, except in so far as it is stronger than No. 74 in the orange. Comparatively weak absorption in the ultra-violet from  $0.20\mu$  to  $0.355\mu$ . There are slight indications of two ultra-violet bands with the intervening region near  $0.29\mu$ . Transparent from  $0.36\mu$  to  $0.49\mu$ . Absorption begins at  $0.49\mu$ , increases to  $0.53\mu$ , then fades to partial transparency near  $0.59\mu$ . Weak absorption from  $0.59\mu$  to  $0.63\mu$ .

## 73. Diamine Black B O. (C.) Sodium salt of ethoxy-diphenyl-disazo-bi-amidonaphthol-sulphonic acid.

Suggested by fig. 22, pl. 6; No. 304, S. & J.

Black powder. In solution blue, blue. 7.5 g. per liter.

Angle  $31.2'$ . Depth 0 to 0.29 mm.

Strong absorption in the yellow and orange with diffuse borders. Red is transmitted. The absorption is somewhat like that of solution No. 74 except in so far as it is stronger than No. 74 in the orange. Absorption decreases from  $0.20\mu$  to about  $0.37\mu$ . Transparent from  $0.37\mu$  to  $0.51\mu$ . Absorption extends from  $0.51\mu$  into the clear red. The maximum of absorption is indefinite.

## 74. Benzopurpurine 10 B. (A.) Sodium salt of dimethoxy-di-phenyl-disazo-bi-naphthionic acid.

Fig. 22, pl. 6; No. 307, S. & J.

Brownish-red powder. In solution red, pink.

5.83 g. per liter.

Angle  $23.4'$ . Depth 0.05 to 0.26 mm.

Chief absorption in the green. The visible band extends from about  $0.48\mu$  to  $0.55\mu$  with its maximum at  $0.515\mu$ . The slanting end of the negative denotes general absorption in the orange.

75. Benzoazurine. Sodium salt of dimethoxy-diphenyl disazo-bi-*a*-naphthol-*p*-sulphonic acid.

Somewhat like fig. 22, pl. 6; No. 311, S. & J.

Bluish-black powder. In solution reddish blue, blue.

7.5 g. per liter.

75. Benzoazurine—*Continued.*

Angle  $25.5'$ . Depth 0 to 0.21 mm.

No very definite, visible band, but a general weakening of the green, yellow, orange, and red. The ultra-violet absorption is weak and ends near  $0.355\mu$ . The region of general absorption begins about  $0.51\mu$  and continues beyond  $0.63\mu$ . There is a weak maximum near  $0.53\mu$ . The end of the negative slants to an unusual degree. The contour of the weak band is V-shaped like the visible band for solution No. 74.

## 76. Diamine Green B. (C.) Sodium salt of diphenyl-disazo-phenol-disulpho-amidonaphthol-azo-nitrobenzene.

No. 372, S. & J. \*

Dull-gray, crystalline powder. In solution bluish green, bluish green.

3 g. per liter.

Angle  $17.0'$ . Depth 0 to 0.14 mm.

Gradual absorption in the orange and red. Very weak absorption in the ultra-violet from  $0.20\mu$  to about  $0.38\mu$ . No visible or photographic absorption between  $0.38\mu$  and  $0.6\mu$ . General absorption begins about  $0.6\mu$ .

## 77. Congo Brown G. (A.) Sodium salt of sulpho-benzene-azo-resorcinol-azodiphenyl-azo-salicylic acid.

Figs. 35 and 36, pl. 9; No. 379, S. & J. Brown powder. In solution light brown, yellow.

4.67 g. per liter.

Angle  $27.3'$ . Depth 0 to 0.25 mm.

Absorption in violet, blue, and green. Very hazy at green side. Absorption decreases from  $0.20\mu$  to a somewhat transparent region around  $0.295\mu$ . Maximum absorption at  $0.365\mu$ . Absorption ceases at  $0.53\mu$ . A weaker solution (fig. 36) showed transparency from  $0.29\mu$  to  $0.315\mu$ . Absorption from  $0.315\mu$  to  $0.428\mu$ . Maximum absorption at  $0.365\mu$ , as before. Transparent to yellow, orange, and red.

## 78. Congo Brown R. (A.) Sodium salt of sulpho-naphthalene-azo-resorcin-azodiphenyl-azo-salicylic acid.

Fig. 35, pl. 9; No. 380, S. & J.

Dark, brownish-red powder. In solution reddish brown, yellow.

Saturated.

Angle  $29.3'$ . Depth 0 to 0.27 mm.

\* Spectrogram too indefinite for reproduction.

78. Congo Brown R—*Continued*.  
Same visible and photographic absorption as No. 77. The change in the constitution is from benzene to naphthalene.
79. Fast Green O. (M.) Dinitroso-resorcinol. (Dioximidoquinone.)  
Similar to fig. 11, pl. 3; No. 394, S. & J. Grayish-brown powder. In solution deep coffee brown, coffee brown. Saturated (heated).  
Angle  $1^{\circ} 6'$ . Depth 0.05 to 0.66 mm.  
General absorption in violet and blue. Similar absorption to that of solution No. 47. The boundaries of the bands, however, are more definite for solution No. 79 than for solution No. 47. From  $0.20\mu$  to  $0.325\mu$  the absorption is complete. Absorption decreases with a long, gradual slope, from  $0.325\mu$  to a minimum of semi-transparency at  $0.475\mu$ . Then a weak band with maximum at  $0.52\mu$  presents itself and continues to  $0.54\mu$ . Only very weak absorption is present from  $0.54\mu$  to  $0.63\mu$ . With the same solution and the cell set for  $35.1'$  and 0.32 mm. the absorption was almost complete from  $0.20\mu$  to  $0.30\mu$  and then sloped gradually to transparency at  $0.405\mu$ . The band at  $0.52\mu$  could not be discerned.
80. Naphthol Green B. (C.) Ferrous sodium salt of nitroso- $\beta$ -naphthol- $\beta$ -monosulphonic acid.  
Fig 10, pl. 3; No. 398, S. & J.  
Dark-green powder. In solution green, light green.  
8.75 g. per liter (boiled).  
Angle  $31.2'$ . Depth 0 to 0.29 mm.  
Absorption in violet and in dark red. Absorption very strong from  $0.20\mu$  to  $0.31\mu$ . Then the absorption decreases very gradually, with a long slant, to  $0.455\mu$ . From  $0.455\mu$  to the orange the transparency is complete. Absorption begins again in the red.
81. Curcumine S. (A.) Sodium salt of the so-called azoxy-stilbene-disulphonic acid.  
Fig. 37, pl. 10; No. 399, S. & J.  
Brown powder. In solution yellow, faint yellow.  
Saturated.  
Angle  $1^{\circ} 10'$ . Depth 0.11 to 0.75 mm.
81. Curcumine S—*Continued*.  
Faint absorption in violet. Absorption decreases from  $0.20\mu$  to  $0.29\mu$ . Transparent from  $0.29\mu$  to  $0.34\mu$ . Weak band from  $0.34\mu$  to  $0.43\mu$  with maximum at  $0.39\mu$ . Transparent from  $0.43\mu$  to  $0.63\mu$ .
82. Auramine O. (B.) Hydrochloride of amido-tetramethyl-diamido-diphenylmethane.  
Fig. 43, pl. 11; No. 425, S. & J.  
Sulphur-yellow powder. In solution yellow, faint yellow.  
Equal volumes of a saturated solution and of water (filtered).  
Angle  $42.5'$ . Depth 0 to 0.36 mm.  
Strong absorption in violet and indigo. Relatively transparent at  $0.22\mu$ . The continuous background of the spark indicates one band or, at most, two bands from  $0.23\mu$  to  $0.275\mu$ . Unusually transparent from  $0.275\mu$  to  $0.345\mu$ . A pair of partially-resolved intense bands absorb from  $0.345\mu$  to  $0.47\mu$ . Their maxima lie at  $0.365\mu$  and  $0.425\mu$ . The intervening, partially-transparent spot is near  $0.385\mu$ . The less refrangible band is the more intense and is very round. Transparent from  $0.470\mu$  to  $0.63\mu$ .
83. Malachite Green. (M.) Oxalate of tetramethyl-di-*p*-amido-triphenylcarbinol.  
Similar to fig. 46, pl. 12; No. 427, S. & J.  
Green, metallic, glistening plates. In solution greenish blue, greenish blue.  
3.75 g. per liter.  
Angle  $25.5'$ . Depth 0 to 0.21 mm.  
Strong, double band in the orange and clear red. Deep red is transmitted. Similar absorption to that of solution No. 86 from  $0.20\mu$  to the yellow. All strong lines in the extreme ultra-violet are transmitted freely. Absorption band lies between  $0.29\mu$  and  $0.33\mu$ . A faint band has its maximum near  $0.425\mu$ . Strong absorption commences at  $0.55\mu$ .
84. Emerald Green. (B.) Sulphate or zinc-double-chloride of tetraethyl-diamido-triphenyl-carbinol.  
Similar to fig. 46, pl. 12; No. 428, S. & J.  
Golden, glistening crystals. In solution green, green.  
4.62 g. per liter.

84. Emerald Green—*Continued*.  
 Angle 31.2'. Depth 0 to 0.29 mm.  
 Compound band in the orange and red with the maximum in the red. The contour is hazy. Similar absorption to solution No. 86 from 0.20 $\mu$  to the yellow, save that the band near 0.425 $\mu$  is hardly discernible on the negative. Strong absorption begins at 0.57 $\mu$ . For ultra-violet details see No. 83 above.
85. Light Green F S. (B.) Sodium salt of dimethyldibenzyl-diamido-triphenyl-carbinol-trisulphonic acid.  
 Similar to fig. 46, pl. 12; No. 434, S. & J.  
 Brownish-black powder. In solution green, green.  
 10 g. per liter.  
 Angle 21.3'. Depth 0 to 0.18 mm.  
 Strong band in the yellow, orange, and red. Except for concentration, the absorption is the same as that of solution No. 86, hence for further details refer to No. 86.
86. Acid Green, concentrated. (C.) Sodium salt of diethyldibenzyl-diamido-triphenyl-carbinol-trisulphonic acid.  
 Fig. 46, pl. 12; No. 435, S. & J.  
 Bright-green, dull powder. In solution deep green, green.  
 13.33 g. per liter.  
 Angle 25.4'. Depth 0 to 0.23 mm.  
 Strong band in orange and red with no return to transparency visible. Absorption in violet and blue. Absorption decreases from 0.20 $\mu$  to about 0.275 $\mu$ . Then a strong band begins, having its maximum near 0.32 $\mu$  and returning abruptly to transparency at 0.34 $\mu$ . Transparent from 0.34 $\mu$  to 0.39 $\mu$ . A round band extends from 0.39 $\mu$  to 0.455 $\mu$  with its maximum at 0.425 $\mu$ . Transparent from 0.455 $\mu$  to 0.55 $\mu$ . Strong absorption commences at 0.55 $\mu$  and increases to complete opacity at 0.63 $\mu$ . Weaker solutions show conclusively the transparent region around 0.275 $\mu$  and also that the band at 0.425 $\mu$  vanishes most readily.
87. Fuchsine—*Continued*.  
 Angle 21.3'. Depth 0 to 0.18 mm.  
 Intense band in blue-green and green. All lines near 0.23 $\mu$  and from 0.25 $\mu$  to 0.26 $\mu$  are freely transmitted. The background indicates a band with its maximum at 0.285 $\mu$  and extending from 0.27 $\mu$  to 0.305 $\mu$ . Transparent from 0.305 $\mu$  to 0.45 $\mu$ . Very strong absorption from 0.45 $\mu$  to 0.575 $\mu$  with maximum near 0.53 $\mu$ . There are probably two unresolved bands of which the more refrangible is the weaker. Transparent from 0.575 $\mu$  to 0.63 $\mu$ . A layer about 1 mm. deep limited the more refrangible, transparent region to the interval from 0.35 $\mu$  to 0.39 $\mu$ .
88. New Magenta. (O.) Hydrochloride of triamido-tritolyl-carbinol.  
 Fig. 50, pl. 13; No. 449, S. & J.  
 Beetle-green powder. In solution red, bluish red.  
 6 g. per liter.  
 Angle 31.2'. Depth 0 to 0.29 mm.  
 Strong band in the green, steeper on the yellow side, and suggesting a sharp band superposed upon a weaker one. The band extends from about 0.44 $\mu$  to 0.56 $\mu$  with its maximum near 0.52 $\mu$ . Transparent from 0.56 $\mu$  to 0.63 $\mu$ .
89. Dahlia. (B.) Mixture of the hydrochlorides or acetates of the mono- or tri-methyl (or ethyl) rosanilines and pararosanilines.  
 Fig. 69, pl. 18; No. 450, S. & J.  
 Green, lumpy powder. In solution deep blue, reddish violet.  
 3.57 g. per liter.  
 Angle 23.4'. Depth 0 to 0.21 mm.  
 Absorption commences in the blue-green, has its maximum in the green-yellow, and decreases gradually into the red. Transparent to deep red. Absorption in ultra-violet is weak. A band which is definite on the more refrangible edge commences at 0.48 $\mu$  and increases to a maximum at 0.52 $\mu$ . A weak, unresolved companion joins the last one near 0.57 $\mu$  and fades away at 0.62 $\mu$ .
90. Crystal Violet. (B.) Hydrochloride of hexamethyl-pararosaniline.  
 Similar to fig. 66, pl. 17; No. 452, S. & J.

90. Crystal Violet—*Continued*.  
 Cantharides glistening crystals. In solution violet, violet.  
 1.38 g. per liter.  
 Angle 42.5'. Depth 0 to 0.36 mm.  
 The absorption is the same as that exhibited by solution No. 92, hence see the description given below.
91. Ethyl Violet. (B.) Hydrochloride of hexaethyl pararosaniline.  
 Fig. 64, pl. 16; No. 453, S. & J.  
 Green, crystalline powder. In solution pure, deep blue, pinkish blue.  
 2.73 g. per liter.  
 Angle 27.3'. Depth 0 to 0.25 mm.  
 Intense absorption in the green. Very sharp and abrupt on the blue side but indefinite on the red border. Strong lines in the ultra-violet are transmitted pretty freely. Relative transparency in the vicinity of 0.265 $\mu$ . Absorption ceases about 0.31 $\mu$  and from this wave-length to 0.495 $\mu$  transparency obtains. At 0.495 $\mu$  an intense band having its maximum at 0.525 $\mu$  begins. About 0.585 $\mu$  the absorption becomes relatively weak and diffuse and continues thus to 0.63 $\mu$ .
92. Methyl Violet 6 B. (A.) Chiefly a mixture of the hydrochlorides of benzylpentamethylpararosanine and hexamethylpararosanine.  
 Fig. 66, pl. 17; No. 454, S. & J.  
 Metallic, glistening powder. In solution blue, reddish blue.  
 2.5 g. per liter.  
 Angle 31.2'. Depth 0 to 0.29 mm.  
 Transmits only blue and pure red in concentrated solution. The solution described below showed two bands, the more intense in the green-yellow and the weaker in the orange. All strong ultra-violet lines are transmitted. The chief band starts at 0.50 $\mu$ , has its maximum at 0.535 $\mu$ , and joins its companion about 0.57 $\mu$ . The weaker band has its maximum at 0.595 $\mu$  and fades away at 0.615 $\mu$ . Transparent from 0.62 $\mu$  to beyond 0.63 $\mu$ .
93. Methyl Green OO. (By.) Zinc-double-chloride of hepta-methyl-pararosanine-chloride.  
 Similar to fig. 47, pl. 12; No. 460, S. & J.  
 Green crystals. In solution greenish blue, greenish blue.
93. Methyl Green OO—*Continued*.  
 6 g. per liter.  
 Angle 19.5'. Depth 0 to 0.18 mm.  
 Band in violet and blue, also strong absorption in orange and red. The band in the orange is partly separated from the stronger band whose intensity increases to, and beyond, 0.63 $\mu$ . With due allowance for differences in concentration, it appears that the absorption is, in toto, the same as that shown by solution No. 94. Absorption decreases from 0.20 $\mu$  to a region of less intense absorption at 0.28 $\mu$ . Then follows a strong band with maximum at 0.315 $\mu$ . A band from 0.375 $\mu$  to 0.445 $\mu$  has its maximum at 0.415 $\mu$ . The yellow and orange band begins at 0.515 $\mu$ .
94. Methyl Green. Zinc-double-chloride of ethylhexamethyl-pararosanine bromide.  
 Fig. 47, pl. 12; No. 461, S. & J.  
 Moss-green, crystalline powder. In solution bluish green, bluish green.  
 20 g. per liter.  
 Angle 19.5'. Depth 0 to 0.18 mm.  
 Band in violet and blue, also strong absorption in orange and red. Transmits green and yellow-green. Band from 0.36 $\mu$  to 0.45 $\mu$  with maximum at 0.415 $\mu$ . This band is steeper on its green side. Very transparent from 0.45 $\mu$  to 0.495 $\mu$ . From 0.495 $\mu$  the absorption is intense and no return to transparency can be seen at 0.63 $\mu$ . The band at 0.415 $\mu$  disappears first on dilution.
95. Fuchsine S. (B.) Mixture of the sodium or ammonium salts of the trisulphonic acids of rosanine and pararosaniline.  
 Fig. 53, pl. 14; No. 462, S. & J.  
 Metallic, green, glistening powder. In solution red, red.  
 3 g. per liter.  
 Angle 23.4'. Depth 0 to 0.21 mm.  
 Strong absorption in the blue-green and green. The middle of the first transparent region is about 0.265 $\mu$ . A weak absorption band has its maximum near 0.295 $\mu$ . The visible band commences at 0.475 $\mu$ , has its maximum about 0.535 $\mu$ , and ends at 0.575 $\mu$ . Transparent from 0.575 $\mu$  to 0.63 $\mu$ .

96. Red Violet 5 R S. (B.) Sodium salt of ethylrosaniline-sulphonic acid.  
Fig. 62, pl. 16; No. 463, S. & J.  
Brownish-violet, metallic, glistening lumps. In solution brownish red, brownish red.  
Saturated.  
Angle 58.5'. Depth 0 to 0.54 mm.  
General absorption in the green, yellow, and orange. The ultra-violet absorption is complete from 0.20 $\mu$  to 0.36 $\mu$ . Absorption decreases gradually from 0.36 $\mu$  to a minimum of general absorption near 0.47 $\mu$ . A weak band has its maximum about 0.525 $\mu$ . The marked slant of the end of the negative shows the presence of appreciable general absorption in the yellow and orange. Red is transmitted.
97. Alkali Blue 6 B. (A. A. C.) Sodium salt of triphenyl-*p*-rosaniline - mono-sulphonic acid.  
Fig. 72, pl. 18; No. 476, S. & J.  
Blue powder. In solution blue, delicate blue.  
12.5 g. per liter (heated).  
Angle 23.4'. Depth 0 to 0.21 mm.  
Strong absorption in yellow, orange, and red. Intense, continuous absorption from 0.20 $\mu$  to 0.32 $\mu$ . Abrupt decrease in absorption from 0.32 $\mu$  to transparency at 0.345 $\mu$ . Transparent from 0.345 $\mu$  to 0.51 $\mu$ . Strong absorption from 0.51 $\mu$  to beyond 0.63 $\mu$ . No decrease in absorption as far as 0.63 $\mu$ . The apparent increase in absorption near 0.62 $\mu$  is due to the relative diminution of sensitiveness of the photographic emulsion.
98. Methyl Blue. (O.) Sodium salt of triphenyl - pararosaniline - trisulphonic acid.  
Similar to fig. 71, pl. 18; No. 479, S. & J.  
Dark-blue powder. In solution deep, bright blue, blue.  
6.89 g. per liter.  
Angle 21.3'. Depth 0 to 0.18 mm.  
Strong absorption in the yellow, orange, and red. The description for solution No. 99 holds here quantitatively.
99. China Blue. (A.) Sodium salt of the trisulphonic acid of triphenylrosaniline and triphenylpararosaniline.  
Fig. 71, pl. 18; No. 480, S. & J.
99. China Blue—*Continued*.  
Coppery flakes. In solution blue, blue. 3.57 g. per liter (filtered).  
Angle 23.4'. Depth 0 to 0.21 mm.  
A hazy-edged band begins in the green and continues into the red. The strong lines around 0.255 $\mu$  are transmitted by the deepest layer of liquid. Absorption is more or less uniform from 0.20 $\mu$  to 0.32 $\mu$  and then shades off to transparency at 0.345 $\mu$ . Transparent from 0.345 $\mu$  to 0.505 $\mu$ . Then a band starts and continues with undiminished intensity to 0.63 $\mu$ .
100. Coralline Red. Dioxy-amido-triphenyl-carbidrid.  
Fig. 49, pl. 13; No. 484, S. & J.  
Reddish-brown lumps. In solution red, salmon pink.  
11.25 g. per liter (heated).  
Angle 19.5'. Depth 0 to 0.18 mm.  
Sharp band in blue and green. Very definite at yellow side with maximum in green-yellow. Rather strong absorption from 0.20 $\mu$  to 0.27 $\mu$ , then a decrease to transparency at 0.315 $\mu$ . Strong absorption from 0.445 $\mu$  to 0.557 $\mu$  with maximum at 0.527 $\mu$ . Probably two unresolved bands with the weaker component at the more refrangible side. Transparent from 0.557 $\mu$  to 0.63 $\mu$ .
101. Night Blue. (B.) Hydrochloride of *p*-tolyltetraethyl-triamido - diphenyl-*a*-naphthyl-carbinol.  
Similar to fig. 70, pl. 18; No. 489, S. & J.  
Violet, bronzy powder. In solution bright blue, blue.  
2.31 g. per liter.  
Angle 23.4'. Depth 0 to 0.21 mm.  
Absorption in the yellow, orange, and red. The limit at the green side is steep and the curve is flat in the longer wave-lengths. The visible region of absorption begins about 0.525 $\mu$ . For the ultra-violet absorption see fig. 70.
102. Victoria Blue 4 R. (B.) Hydrochloride of phenylpenta-methyl-triamido-diphenyl - *a* - naphthyl - carbinol.  
Fig. 70, pl. 18; No. 490, S. & J.  
Bronzy, glistening powder. In solution deep blue, reddish blue.  
2.78 g. per liter (heated).  
Angle 27.3'. Depth 0 to 0.25 mm.

102. Victoria Blue 4 R—*Continued*.  
Hazy-edged absorption in yellow and orange. The red is only partially absorbed. Comparatively weak absorption decreases steadily from  $0.20\mu$  to about  $0.335\mu$ . A band commences at  $0.495\mu$  and continues to a maximum at  $0.53\mu$ . From this point the band shades off gently towards the red. (The apparent increase of absorption at  $0.62\mu$  is probably due to the increasing lack of sensitiveness of the plate.)
103. Rhodamine B. (B.) Hydrochloride of diethyl-*m*-amido-phenol-phthaleïne.  
Fig. 65, pl. 17; No. 504, S. & J.  
Reddish-violet powder. In solution bluish red, violet.  
7.5 g. per liter.  
Angle  $42.5'$ . Depth 0 to  $0.36$  mm.  
Two distinct bands, the one in the yellow-orange and the other in the green-yellow. Eye observations, changes in concentration, and different makes of films show that the more refrangible band is the more intense. Fluorescent solution. Absorption decreases gradually from  $0.20\mu$  to an indefinite limit near  $0.32\mu$ . Strong absorption from  $0.494\mu$  to about  $0.59\mu$ . The maxima are at  $0.524\mu$  and  $0.557\mu$  with the intervening minimum of absorption at  $0.54\mu$ . Transparent beyond the orange band into the red.
104. Fast Acid Violet B. (M.) Sodium salt of diphenyl-*m*-amido-phenol-phthaleïn sulphonic acid.  
Fig. 63, pl. 16; No. 506, S. & J.  
Maroon powder. In solution bluish red, pink.  
3.33 g. per liter.  
Angle  $27.3'$ . Depth 0 to  $0.25$  mm.  
Absorption band in the green-yellow. This band is comparatively definite on the green side and has a shadowy companion on the red side. General absorption continues well into the orange-red. All strong lines in the ultra-violet are transmitted. The ultra-violet absorption ends about  $0.33\mu$ . The visible band begins at  $0.505\mu$  and has its maximum near  $0.53\mu$ . The less refrangible limit is indeterminate. The essential difference between the spectrograms for solutions Nos. 104 and 106 is that
104. Fast Acid Violet B—*Continued*.  
for the former the visible band is asymmetric, whereas for the latter it is symmetric.
105. Fast Acid Violet A 2 R. (M.) Sodium salt of di-*o*-tolyl-*m*-amido-phenol-phthaleïn-sulphonic acid.  
Similar to fig. 19, pl. 5; No. 507, S. & J.  
Violet-red powder. In solution red, pink.  
4.67 g. per liter.  
Angle  $23.4'$ . Depth 0 to  $0.21$  mm.  
Very narrow, definite band in the green. All strong ultra-violet lines are transmitted. The ultra-violet absorption ends about  $0.335\mu$ . The visible band begins at  $0.495\mu$ , has its maximum at  $0.525\mu$ , and ends near  $0.57\mu$ . The slanting end of the spectrogram indicates general absorption in the deep yellow. The green band for this solution is of the same type as the corresponding one for No. 104, although it is much less asymmetric, and therefore it resembles more closely No. 106. The spectrum of solution No. 105 is best described as a transition form between Nos. 104 and 106. Solutions Nos. 104 and 105 have the same empirical formulæ.
106. Acid Rosamine A. (A.) Sodium salt of di-*mesidyl*-*m*-amido-phenol-phthaleïn-sulphonic acid.  
Fig. 19, pl. 5; No. 508, S. & J.  
Light-red powder. In solution red, pink.  
10 g. per liter.  
Angle  $29.3'$ . Depth 0 to  $0.27$  mm.  
Single V-shaped band in the green. Weak absorption beginning with extinction at  $0.20\mu$  and fading gradually to transparency at  $0.32\mu$ . Absorption band covers the interval from  $0.505\mu$  to  $0.565\mu$  with its maximum at  $0.535\mu$ . Transparent from  $0.565\mu$  to  $0.63\mu$ .
107. Uranine. (B.) Sodium or potassium salt of fluoresceïne.  
Figs. 15 and 16, pl. 4; No. 510, S. & J.  
Yellowish-brown powder. In solution reddish yellow, yellow.  
Intense, narrow band in the blue-green with a weaker companion on its more refrangible side. Very strong, yellowish-green fluorescence.

107. Uranine—*Continued*.

Fig. 16 resulted from a solution of 2 g. per liter.

Angle 23.4'. Depth 0 to 0.21 mm. Only the stronger band shows. Here it extends from  $0.480\mu$  to  $0.504\mu$  with its maximum at  $0.493\mu$ .

Fig. 15 corresponds to 2.67 g. per liter.

The angle 31.2' gives a maximum depth of 0.49 mm. Complete transparency from  $0.330\mu$  to  $0.443\mu$ . The spectrogram shows that the visible region of absorption has roughly parallel sides which are very definite. The visible maximum is at  $0.493\mu$  as before. At the outer edge of the fifth strip the absorption covers the interval from  $0.443\mu$  to  $0.515\mu$ .

A solution of 5 g. per liter, of angle 42.5', and of depth 0 to 0.36 mm., absorbed from  $0.432\mu$  to  $0.518\mu$  with the maximum at  $0.493\mu$ .

A solution of 20 g. per liter with an angle of 42.5' caused the ultra-violet and visible absorption bands to coalesce, on the third photographic strip, in a semi-transparent region extending roughly from  $0.355\mu$  to  $0.395\mu$ . Intense absorption from  $0.395\mu$  to  $0.533\mu$ . The short wavelength boundary is indefinite, but the opposite limit is very sharply defined and steep. Maximum absorption at  $0.493\mu$ .

Tests were made to ascertain whether or not the conditions were favorable to contamination of the absorption spectra by the fluorescent light. The most dilute solution was illuminated with intense ultra-violet light and an exposure of five minutes was given to the photographic film. Full development of the film brought out no trace of previously incident light. Therefore, since the Nernst glower alone was used in making the records of the visible bands and because, in all cases except one, more concentrated solutions were used, it follows that the spectrograms are correct representations of the absorption, at least so far as the fluorescent light is concerned.

## 108. Eosine, yellowish. (A.) Alkali salts of tetrabromo-fluoresceine.

Fig. 58, pl. 15; No. 512, S. & J.

108. Eosine, yellowish—*Continued*.

Deep red powder. In solution yellowish red, pink.

20 g. per liter.

Angle 21.3'. Depth 0 to 0.18 mm.

Very strong absorption in blue and green. Faint green fluorescence increasing with dilution. Intense absorption from  $0.20\mu$  to  $0.33\mu$ . The absorption then decreases, first gradually and then steeply, to partial transparency at  $0.37\mu$ . This transparent region continues as far as  $0.434\mu$ . Intense absorption from  $0.434\mu$  to  $0.56\mu$ . From  $0.515\mu$  to  $0.525\mu$  the solution is almost opaque. Two unresolved bands seem to be present. The more refrangible boundary of the visible absorption is less definite than the opposite side. The latter limit is steep and sharp. Transparent from  $0.56\mu$  to  $0.63\mu$ .

## 109. Eosine à l'alcool. (B.) Potassium salt of tetrabromo-fluoresceine-ethyl-ether.

Fig. 17, pl. 5; No. 514, S. & J.

Brown powder mixed with small green crystals. In solution red, pink. 4.29 g. per liter (heated).

Angle 46.8'. Depth 0 to 0.43 mm.

Sharp, narrow band in green, abrupt on yellow side and diffuse on the blue side due to a faint companion band. Slight greenish-yellow fluorescence. Very weak absorption in extreme ultra-violet. Absorption begins at  $0.495\mu$  and ends at  $0.540\mu$ . The chief maximum is at  $0.525\mu$ . Transparent from  $0.540\mu$  to  $0.63\mu$ .

## 110. Methyl Eosine. (A.) Potassium salt of dibromodinitro-fluoresceine.

Similar to fig. 58, pl. 15; No. 515, S. & J.

Brown, crystalline powder. In solution red, orange.

10 g. per liter.

Angle 15.6'. Depth 0 to 0.14 mm.

Intense band in blue and green. Apparently two unresolved bands. Similar absorption to that of solution No. 108. Absorption is rather complete from  $0.20\mu$  to  $0.30\mu$  and then decreases to about  $0.36\mu$ . Strong absorption from  $0.46\mu$  to  $0.56\mu$ . The principal maximum is at  $0.52\mu$ . Very transparent from  $0.56\mu$  to  $0.63\mu$ .

111. Eosine, bluish. (B.) Sodium salt of tetraiodo-fluoresceine.  
 Similar to fig. 58, pl. 15; No. 517, S. & J.  
 Lavender powder. In solution red, pink.  
 15 g. per liter.  
 Angle 21.3'. Depth 0 to 0.18 mm.  
 Intense absorption in the blue-green. Similar absorption to that of solution No. 108. The yellowish-green fluorescence only appears in dilute solutions. Absorption decreases gradually from 0.20 $\mu$  to 0.36 $\mu$ . Intense absorption from 0.455 $\mu$  to 0.555 $\mu$ . Maximum of absorption at 0.52 $\mu$ . There seem to be two unresolved bands of which the more refrangible is a little less intense than its companion. This region of absorption is sharper and steeper at its yellow border. Transparent from 0.555 $\mu$  to 0.63 $\mu$ .
112. Erythrosine. (M.) Sodium salt of tetraiodo-fluoresceine.  
 Fig. 59, pl. 15; No. 517, S. & J.  
 Dark-red powder. In solution red, pink.  
 15 g. per liter.  
 Angle 21.3'. Depth 0 to 0.18 mm.  
 Intense absorption in the blue and green. A strong band in the middle with a slightly weaker, unresolved companion on each side. The yellowish-green fluorescence only appears in dilute solutions. The region of visible absorption is from 0.455 $\mu$  to 0.562 $\mu$ . The chief maximum is about 0.518 $\mu$ . The yellow edge of this group of bands is very sharply defined. Transparent from 0.562 $\mu$  to 0.63 $\mu$ .
113. Cyanosine. (M.) Alkaline salt of tetra-bromodichloro-fluoresceine-methyl-ether.  
 Fig. 18, pl. 5; No. 519, S. & J.  
 Brownish-red powder. In solution red, bluish pink.  
 Saturated (boiled).  
 Angle 25.4'. Depth 0 to 0.23 mm.  
 Band in blue-green and green. Faint, yellowish fluorescence. Strong absorption from 0.493 $\mu$  to 0.553 $\mu$  with its maximum at 0.525 $\mu$ . Transparent from 0.553 $\mu$  to 0.63 $\mu$ .
114. Rose Bengal. (B.) Alkaline salt of tetraiododichloro-fluoresceine.  
 Similar to fig. 59, pl. 15; No. 520, S. & J.  
 Brown powder. In solution red, orange. 15 g. per liter.  
 Angle 21.3'. Depth 0 to 0.18 mm.  
 Double, unresolved pair of bands in green. In amyl alcohol the bands were nearly resolved. Strong absorption from 0.20 $\mu$  to about 0.33 $\mu$ , except a slight weakening at 0.295 $\mu$ . Transparent from 0.33 $\mu$  to 0.48 $\mu$ . Strong absorption from 0.48 $\mu$  to 0.575 $\mu$ . Transparent from 0.575 $\mu$  to 0.63 $\mu$ .
115. Phloxine. (B.) Sodium salt of tetra-bromotetra-chloro-fluoresceine.  
 Fig. 60, pl. 15; No. 521, S. & J.  
 Brick-red powder. In solution cherry red, pink.  
 12.5 g. per liter.  
 Angle 42.5'. Depth 0 to 0.36 mm.  
 Intense absorption in the green. Dark-green fluorescence. Visible band lies between 0.458 $\mu$  and 0.57 $\mu$ . The maximum is near 0.525 $\mu$ . For dilute solutions the absorption is very much like that shown by fig. 18, except that the contour of the band in the green is sharper than for solution No. 113.
116. Galleine. (By.) Pyrogallol-phthalein.  
 Similar to fig. 11, pl. 3; No. 525, S. & J.  
 Violet brown powder. In solution very dark brown, brown.  
 Saturated (heated).  
 Angle 58.5'. Depth 0 to 0.54 mm.  
 Hazy-edged absorption in the blue-green and green. Absorption is comparatively strong at 0.20 $\mu$  and decreases very gradually to semi-transparency about 0.435 $\mu$ . Only partial transparency exists between 0.435 $\mu$  and 0.485 $\mu$ . A V-shaped band absorbs from 0.485 $\mu$  to 0.553 $\mu$ . The maximum is about 0.52 $\mu$ . The end of the negative slants a good deal, showing general absorption in the yellow-orange. The spectrogram is like that which would be obtained with a more concentrated solution of No. 47 if it were possible to produce such a condition.



117. Phosphine. (M.) Nitrate of chrysaniline (unsym. diamido-phenyl-acridine) and homologues.  
Fig. 32, pl. 8; No. 532, S. & J.  
Orange-yellow powder. In solution brown, yellow.  
11.25 g. per liter (heated and filtered).  
Angle 27.3'. Depth 0 to 0.25 mm.  
Absorption in violet, blue, and green with hazy limits. Strong absorption from 0.20 $\mu$  to 0.295 $\mu$ , then weakening to semi-transparency at 0.325 $\mu$ . Next a band with maximum at 0.36 $\mu$ . Return to partial transparency at 0.41 $\mu$ . Then follow two unresolved bands with maxima about 0.458 $\mu$  and 0.50 $\mu$ . Complete transparency from 0.52 $\mu$  to 0.62 $\mu$ . A solution so concentrated as to absorb all the ultra-violet and visible spectrum from 0.20 $\mu$  to 0.538 $\mu$  was transparent to 0.63 $\mu$ .
118. Alizarine Brown. (M.) Trioxyanthraquinone.  
Similar to fig. 11, pl. 3; No. 538, S. & J.  
Dark-brown powder. In solution dull brown, brown.  
Saturated.  
Angle 35.1'. Depth 0 to 0.32 mm.  
General, indefinite absorption except in the red. Absorption intense and uniform from 0.20 $\mu$  to 0.33 $\mu$ . From 0.33 $\mu$  the absorption decreases very gradually and nearly linearly to about 0.47 $\mu$ . A very weak band with its maximum at 0.52 $\mu$  exists over and above the intensity minimum of the sensitized film. The end of the negative slopes appreciably, denoting continued general absorption in the orange. No visible weakening of the red. A maximum of transparency is around 0.48 $\mu$ . The spectrograms for solutions Nos. 116 and 118 are very similar.
119. Alizarine Red S. (B.) Sodium salt of alizarine-monosulphonic acid.  
Fig. 14, pl. 4; No. 546, S. & J.  
Orange-yellow powder. In solution reddish yellow, yellow.  
12 g. per liter (heated and filtered).  
Angle 30.0'. Depth 0 to 0.45 mm.  
Absorption in violet and blue. Opaque from 0.20 $\mu$  to 0.275 $\mu$ . Absorption decreases gradually from 0.275 $\mu$  to partial transparency at 0.377 $\mu$ , and then increases to a maximum at 0.42 $\mu$ . Absorption ends at 0.485 $\mu$ . No visible absorption from 0.49 $\mu$  to 0.63 $\mu$ .
119. Alizarine Red S.—Continued.  
then increases to a maximum at 0.42 $\mu$ . Absorption ends at 0.485 $\mu$ . No visible absorption from 0.49 $\mu$  to 0.63 $\mu$ .
120. Alizarine Blue S. (B.) Sodium bisulphite compound of dioxy-anthraquinone- $\beta$ -quinoline.  
Fig. 28, pl. 7; No. 563, S. & J.  
Chocolate-brown powder. In solution yellowish brown, brown.  
7.37 g. per liter.  
Angle 58.5'. Depth 0 to 0.54 mm.  
Absorption in violet, blue, and green.  
The absorption extends into the ultra-violet. Absorption from 0.20 $\mu$  to 0.33 $\mu$  is almost complete save a slight weakening around 0.285 $\mu$ . Intense maximum at 0.315 $\mu$ . Absorption decreases abruptly from beyond 0.33 $\mu$  to transparency at 0.36 $\mu$ . The transparent region is from 0.36 $\mu$  to about 0.385 $\mu$ . A pair of wide bands absorbs from 0.385 $\mu$  to 0.543 $\mu$ . Their maxima are at 0.44 $\mu$  and 0.517 $\mu$ . The intervening minimum of absorption is at 0.48 $\mu$ . Transparent from 0.543 $\mu$  to 0.63 $\mu$ . The ultra-violet bands remain very intense even when dilution causes the visible bands to disappear.
121. Neutral Red. (D. H.) Hydrochloride of dimethyldiamido-toluphenazine.  
Similar to fig 54, pl. 14; No. 580, S. & J.  
Dark-green powder. In solution red, pink.  
3 g. per liter.  
Angle 39.0'. Depth 0 to 0.36 mm.  
Band in blue and blue-green, not sharp at edges. Very similar absorption to that of solution No. 122. Slight transparency at 0.23 $\mu$ . A band lies between this point and 0.31 $\mu$  where transparency begins to be complete. An absorption band extends from 0.468 $\mu$  to 0.545 $\mu$  with its maximum at 0.507 $\mu$ . Transparent from 0.545 $\mu$  to 0.63 $\mu$ .
122. Phenosafranine. Diamidophenyl-phenazonium chloride.  
Fig. 54, pl. 14; No. 583, S. & J.  
Green, glistening crystals. In solution clear red, pink.  
2.5 g. per liter.  
Angle 39.0'. Depth 0 to 0.36 mm.

122. Phenosafranine—*Continued*.  
Band in blue and blue-green, not sharp at edges. The ultra-violet band ends about  $0.31\mu$ . The visible band absorbs from  $0.45\mu$  to  $0.545\mu$  with maximum at  $0.50\mu$ . Transparent from  $0.545\mu$  to  $0.63\mu$ .
123. Safranine. (B.) Mixture of diamidophenyl- and tolyl-tolazonium chlorides.  
Similar to fig. 54, pl. 14; No. 584, S. & J.  
Reddish-brown powder. In solution red, red.  
5 g. per liter.  
Angle  $27.3'$ . Depth 0 to  $0.25\mu$ .  
Definite absorption in blue-green and green. Similar absorption to that of solution No. 122. Strong absorption from  $0.20\mu$  to  $0.28\mu$ . Rapid decrease in absorption from  $0.28\mu$  to  $0.32\mu$ . Absorption begins again at  $0.44\mu$ , increases to a maximum near  $0.495\mu$ , and then decreases to transparency at  $0.555\mu$ . Transparent from  $0.555\mu$  to  $0.63\mu$ .
124. Heliotrope 2 B. (A.) Dimethyldiamido-xylyl-xylophen-azonium chloride.  
Fig. 68, pl. 17; No. 590, S. & J.  
Grayish-green powder. In solution reddish violet, reddish violet.  
7 g. per liter.  
Angle  $27.3'$ . Depth 0 to  $0.25\mu$ .  
Strong band in yellow and orange. Transparent to deep red. Strong absorption from  $0.48\mu$  to  $0.605\mu$  with maximum near  $0.535\mu$ . Increasing transparency from  $0.605\mu$  into the red.
125. Rosolane O. (M.) Phenyl-diamidophenyl-toluphen-azonium chloride.  
Similar to fig. 19, pl. 5; No. 591, S. & J.  
Olive-green powder. In solution deep violet, faint, reddish violet.  
9 g. per liter (warmed and filtered).  
Angle  $35.1'$ . Depth 0 to  $0.32\mu$ .  
Weak band in the green broadening out into general absorption on the red side. Somewhat similar absorption to that of solution No. 106. The visible band is definitely V-shaped and slopes more at its less refrangible side than at its blue boundary. Slight transparency at  $0.23\mu$  is followed by a maximum of
125. Rosolane O—*Continued*.  
absorption near  $0.27\mu$ . Absorption ceases about  $0.33\mu$  and begins again at  $0.495\mu$ . The latter band has its maximum at  $0.525\mu$  and fades into general absorption around  $0.563\mu$ . The end of the positive slants appreciably, thus emphasizing the general absorption in the orange. Transparent to the red.
126. Nigrosine, soluble. (A.) Sodium salts of sulphonic acids of spirit nigrosines.  
Somewhat like figs. 20 and 21 of pls. 5 and 6, respectively; No. 602, S. & J.  
Coal-black, glistening lumps. In solution blackish blue, dull blue.  
Saturated.  
Angle  $31.2'$ . Depth 0 to  $0.29\mu$ .  
Very indefinite absorption in the yellow and orange. The ultra-violet absorption is like that of solution No. 127, while the visible absorption is similar to that of solution No. 46. However, the band at  $0.528\mu$  is incomparably weaker than the corresponding band of solution No. 46. Absorption rather strong between  $0.20\mu$  and  $0.30\mu$ . From  $0.30\mu$  the absorption decreases to transparency at  $0.35\mu$ . Different photographic emulsions show a weak band about  $0.528\mu$ . Absorption continues general into the red, as is shown by the appreciable slant of the end of the negative.
127. Naphthalene Red. Mixture of amidonaphthyl-naphthazonium chloride and diamido-naphthyl-naphthazonium chloride.  
Fig. 20, pl. 5; No. 614, S. & J.  
Dark-brown powder. In solution red, faint pink.  
Saturated (heated).  
Angle  $31.2'$ . Depth 0 to  $0.29\mu$ .  
Hazy-edged absorption band in the green. The visible band extends from  $0.488\mu$  to  $0.545\mu$  with its maximum at  $0.517\mu$ . The slight inclination at the red end of the negative shows appreciable decrease of transparency, between  $0.545\mu$  and  $0.63\mu$ , with increase of thickness of absorbing layer.
128. Alizarine Green B. (D.) Dioxy-naphthazonium sulphonate.  
No. 647, S. & J.\*

\* Spectrogram too indefinite for reproduction.

128. Alizarine Green B—*Continued*.  
Dark-green powder. In solution dark green, light green.  
20 g. per liter (heated and filtered).  
Angle  $31.2'$ . Depth 0.26 to 0.55 mm.  
General absorption in the violet, orange, and red. The minimum of absorption lies in the green, of course. When the depth was 0 to 0.29 mm., the ultra-violet absorption ended at about  $0.355\mu$ . There is no sharp band in the ultra-violet, but simply one-sided absorption, decreasing from  $0.20\mu$  towards the longer wave-lengths.
129. Columbia Yellow. (A.) Oxidation products of dehydrothiolumidine-sulphonic acid or of the latter and primuline together.  
Fig. 13, pl. 3; No. 663, S. & J.  
Brownish-yellow powder. In solution yellow, light yellow.  
10 g. per liter (warmed).  
Angle  $31.2'$ . Depth 0 to 0.29 mm.  
Weak-edged absorption in violet. Uniform absorption from  $0.20\mu$  to about  $0.36\mu$ . Then a steady decrease in absorption to  $0.45\mu$ . Complete transparency from  $0.45\mu$  to  $0.63\mu$ .
130. Quinoline Blue. (G.) No. 664, S. & J.  
Glistening, green crystals. In solution delicate violet, pink.  
Saturated (heated).  
Angle  $0^\circ$ . Depth 134 mm.  
Only the blue and blue-green faintly transmitted. (No photograph was taken for the saturated solution.)  
When 44 cc. of the saturated solution was diluted to 100 cc. a strong band appeared in the yellow and orange, while the red was freely transmitted. The ultra-violet absorption extends to  $0.40\mu$  and fades out about  $0.42\mu$ . Weak absorption begins at  $0.48\mu$  and increases to opacity near  $0.55\mu$ . Complete absorption continues to about  $0.607\mu$ . Absorption decreases rapidly from  $0.607\mu$  to  $0.63\mu$ . When 44 cc. of the saturated solution was made up to 112 cc. and a column 15 cm. was used, no definite band could be seen, but only a faint weakening of the orange. The ultra-violet absorption was, however, complete as far as  $0.374\mu$  and vanished near  $0.395\mu$ .
131. Quinoline Yellow, soluble in water. (A.) Quinoline Yellow O. (M.) Sodium salt of the sulphonic acid (chiefly disulphonic acid) of quinophthalone.  
Fig. 44, pl. 11; No. 667, S. & J.  
Yellow powder. In solution lemon yellow, faint yellow.  
17.5 g. per liter.  
Angle  $27.3'$ . Depth 0 to 0.25 mm.  
Strong band in extreme violet. One-sided absorption in ultra-violet ends about  $0.33\mu$ . Transparent region from  $0.33\mu$  to  $0.345\mu$ . A band commences at  $0.345\mu$ , has its maximum at  $0.40\mu$ , and joins a narrow, companion band at  $0.438\mu$ . Maximum of little band is about  $0.448\mu$  and complete transparency extends from  $0.453\mu$  to  $0.63\mu$ . For a 5-strip negative the absorption only advanced to  $0.463\mu$ .
132. Indigo Carmine, dry. Sodium salt of indigotine disulphonic acid.  
No. 692, S. & J.  
Deep-violet powder. In solution blue, blue.  
10 g. per liter.  
Angle  $23.4'$ . Depth 0 to 0.21 mm.  
Transmits green and yellow. Moderately intense band in the orange-red, beginning about  $0.555\mu$  and increasing beyond  $0.63\mu$ . General absorption from  $0.20\mu$  to complete transparency at  $0.37\mu$ .
133. Acid Magenta S. (A.) Similar to fig. 53, pl. 14.  
Dark-green powder. In solution bluish red, bluish pink.  
10 g. per liter.  
Angle  $15.6'$ . Depth 0 to 0.14 mm.  
Strong band in the green with abrupt edges. Violet, indigo, orange, and red are transmitted. Similar absorption to that of solution No. 95. Partial transparency in the vicinity of  $0.265\mu$ . A comparatively weak, narrow band has its maximum near  $0.295\mu$ , and absorption ceases about  $0.325\mu$ . An intense region of absorption begins at  $0.46\mu$ , has its maximum at  $0.535\mu$ , and ends at  $0.58\mu$ . Therefore this region slants more at the violet border than at the orange side. The band is very smooth and round.

134. Alizarine Orange. (Powder 80 per cent.) (M.)  
Fig. 24, pl. 6.  
Very deep-purple powder. In solution dark red, red.  
5.83 g. per liter (warmed and filtered).  
Angle 27.3'. Depth 0 to 0.25 mm.  
Weak, shadowy band in the green-yellow, gradually fading away in the red. The ultra-violet absorption is intense and one-sided, and ceases about 0.39 $\mu$ . The visible band begins near 0.48 $\mu$ , has its maximum at 0.525 $\mu$ , and fades into general absorption about 0.56 $\mu$ . The end of the negative slopes to an unusual extent, showing that the general absorption is relatively strong.
135. Alizarine Red No. 1. 40 per cent. (M.)  
Similar to fig. 11, pl. 3.  
Yellow paste. In solution deep yellow, yellow.  
Saturated.  
Angle 31.2'. Depth 0 to 0.29 mm.  
Absorption very weak, general, and indefinite. A few mm. of the solution show complete opacity. The solution looks like a milky but yellow emulsion. The ultra-violet absorption is relatively weak, is quite general, and fades away to semi-transparency near 0.4 $\mu$ . A slight weakening of transparency around 0.52 $\mu$  may be the fault of the sensitized film. The end of the negative slopes quite enough to indicate continued absorption in the orange. No visible absorption in the red.
136. Aurophosphine 4 G. (A.)  
Fig. 45, pl. 12.  
Reddish-brown powder. In solution clear yellow, yellow.  
11.67 g. per liter.  
Angle 27.3'. Depth 0 to 0.25 mm.  
Strong absorption in the violet and indigo. Absorption decreases from 0.20 $\mu$  to a maximum at 0.245 $\mu$  and then follows a rounded curve to transparency at 0.305 $\mu$ . Unusual transparency from 0.305 $\mu$  to 0.390 $\mu$ . As for *p*-nitrosodimethyl aniline, so here, all the strong lines between 0.324 $\mu$  and 0.363 $\mu$  are transmitted with almost no decrease of intensity. A V-shaped band absorbs from 0.390 $\mu$  to 0.470 $\mu$  with its max-
136. Aurophosphine 4 G.—Continued.  
imum at 0.430 $\mu$ . Transparent from 0.470 $\mu$  to 0.63 $\mu$ .
137. Brilliant Croceine, blue shade. (M.)  
Similar to fig. 52, pl. 13.  
Bright-red powder. In solution red, salmon pink.  
7 g. per liter.  
Angle 25.4'. Depth 0 to 0.23 mm.  
Strong band in blue-green and green. It slopes more on the blue than on the yellow border. Similar absorption to that of solutions Nos. 21 and 43. Absorption decreases from 0.20 $\mu$  to a region of partial transparency in the vicinity of 0.29 $\mu$ . A symmetrical, hazy band absorbs from about 0.305 $\mu$  to 0.385 $\mu$ . A strong band absorbs from 0.458 $\mu$  to 0.558 $\mu$  with its maximum near 0.518 $\mu$ .  
Transparent to the orange and red.
138. Brilliant Purpurine 10 B. (A.)  
Similar to fig. 21, pl. 6.  
Grayish-violet powder. In solution red, bluish red.  
5.83 g. per liter (warmed).  
Angle 23.4'. Depth 0 to 0.21 mm.  
Shadowy band in the green with general absorption in the yellow and orange. Similar absorption to that of solution No. 46. Absorption decreases from 0.20 $\mu$  to a semi-transparent region around 0.29 $\mu$ . A symmetrical, hazy band absorbs from about 0.30 $\mu$  to 0.38 $\mu$ . Another band begins near 0.48 $\mu$ , has its maximum at 0.52 $\mu$ , and ends at 0.555 $\mu$ . The end of the negative slants at an angle of about 30°, thus emphasizing the strong, general absorption in the yellow-orange.
139. Carthamin.  
Similar to fig. 13, pl. 3.  
Reddish-brown plates. In solution brownish red, faint brown.  
Concentrated.  
Angle 31.2'. Depth 0 to 0.29 mm.  
One-sided absorption in the ultra-violet. Absorption similar to that of solution No. 129. Absorption was strong from 0.20 $\mu$  to about 0.34 $\mu$ . From this wave-length on, the absorption curve is round and slopes to 0.445 $\mu$  at the edge of the spectrogram farthest from the comparison spectrum. Transparent from 0.445 $\mu$  to beyond 0.63 $\mu$ . The slope

139. Carthamin—*Continued*.  
of the blue side of the band is the same as the corresponding region of solution No. 119.
140. Columbia Fast Scarlet 4 B. (A.)  
Similar to fig. 26, pl. 7.  
Red powder. In solution yellowish red, pink.  
5.83 g. per liter.  
Angle 27.3'. Depth 0 to 0.25 mm.  
Broad absorption in the blue, blue-green, and green. The contour is somewhat hazy. The spectrum is almost identical with fig. 26 for solution No. 69, therefore the wavelengths are not repeated here.
141. Dianil Orange G. (M.)  
Fig. 34, pl. 9.  
Brick-red, glistening powder. In solution yellowish red, yellow.  
11.67 g. per liter.  
Angle 23.4'. Depth 0 to 0.21 mm.  
Uniform absorption from the blue border of the green to the extreme violet and beyond. Except for slight, wavy regions, the absorption decreases almost linearly from 0.20 $\mu$  to about 0.53 $\mu$ . At this point it ends rather abruptly. Transparent from 0.53 $\mu$  to 0.63 $\mu$ .
142. Fluoresceine. Tetraoxypythalophenone anhydride  $C_{20}H_{12}O_5 + H_2O$ .  
Cinnabar-red powder. In solution faint yellow.  
Saturated (boiled).  
Angle 0°. Depth 3.7 mm.  
Weak band in blue and blue-green.  
Intense, green fluorescence. Absorption complete from 0.20 $\mu$  to 0.25 $\mu$  and then decreases to transparency at 0.29 $\mu$ . Weak absorption extends from about 0.46 $\mu$  to 0.505 $\mu$ .
143. Guinea Carmine B. (A.)  
Similar to fig. 20, pl. 5.  
Brown powder. In solution red, pink. Saturated.  
Angle 2° 17'. Depth 0.26 to 1.51 mm.  
Absorption in green. No lines transmitted between 0.20 $\mu$  and 0.273 $\mu$ . (Non-zero depth of liquid.) Weak absorption from 0.273 $\mu$  to 0.33 $\mu$ . Transparent from 0.33 $\mu$  to 0.493 $\mu$ . A hazy-edged band extends from 0.493 $\mu$  to 0.548 $\mu$  with its maximum at 0.521 $\mu$ . Transparent from 0.548 $\mu$  to 0.63 $\mu$ . The spectrogram for solution No. 143 does not slant at the
143. Guinea Carmine B—*Continued*.  
red limit, whereas that for solution No. 127 does.
144. Orcein.  
Suggested by figs. 20 and 21 of pls. 5 and 6, respectively.  
Black powder with reddish tinge. In solution deep red, light red.  
Saturated (heated and filtered).  
Angle 31.2'. Depth 0 to 0.29 mm.  
Weak, narrow band in the yellow. The ultra-violet absorption is similar to that of solution No. 127. The absorption in the visible spectrum is somewhat like that of solution No. 46. However, the band in the yellow is very much weaker and narrower for solution No. 144 than for the corresponding band of solution No. 46. Strong absorption from 0.20 $\mu$  to 0.27 $\mu$  was followed by a gradual decrease to transparency near 0.33 $\mu$ . Transparent from 0.33 $\mu$  to about 0.515 $\mu$ . A narrow, hazy-edged absorption band, with its maximum at 0.525 $\mu$ , extended from 0.515 $\mu$  to 0.542 $\mu$  approximately. The very marked slant of the end of the spectrogram showed the presence of comparatively intense, general absorption in the orange.
145. Soluble Prussian Blue.  
Deep-blue, glistening powder. In solution deep blue, blue.  
1.76 g. per liter.  
Angle 21.3'. Depth 0 to 0.18 mm.  
Strong absorption in the yellow, orange, and red. Almost opaque from 0.20 $\mu$  to 0.28 $\mu$ . Absorption decreases very gradually from 0.28 $\mu$  to 0.38 $\mu$ . The visible region of absorption begins at 0.505 $\mu$  and continues to 0.63 $\mu$  and beyond.
146. Thiogene Brown S. (M.)  
Similar to fig. 11, pl. 3.  
Bluish-black lumps. In solution dull brown, brown.  
Saturated.  
Angle 27.3'. Depth 0 to 0.25 mm.  
General weakening of all the visible spectrum except the blue and red. The solution smells strongly of hydrogen sulphide. (The odor is not so marked for the dry dye.) Similar absorption to that of solution No. 47. Absorption decreases very gradually from 0.20 $\mu$  to about

146. Thiogene Brown S—*Continued*.  
 $0.41\mu$ . On both sides of  $0.445\mu$  the absorption is at a minimum. A very shadowy band absorbs from  $0.49\mu$  to  $0.545\mu$ . Its maximum is near  $0.523\mu$ . The end of the negative slants a good deal more than that of solution No. 47, and thus points to the absorption in the yellow and orange.
147. Thiogene Orange R. (M.)  
 Similar to fig. 12, pl. 3.  
 Brown powder. In solution reddish brown, yellow.  
 $5.83$  g. per liter (filtered).  
 Angle  $50.7'$ . Depth 0 to  $0.46$  mm.  
 Weak absorption in the violet. The solution has an unpleasant odor. Its absorption is similar to that of solution No. 30. Absorption is complete from  $0.20\mu$  to  $0.25\mu$  and then decreases with a long, gentle curve to transparency about  $0.445\mu$ . Transparent from  $0.445\mu$  to  $0.63\mu$ .
- MISCELLANEOUS ABSORBING MEDIA.
148. Acetone, Ethyl Alcohol, Methyl Alcohol, and Water.  
 Fig. 87, pl. 22.  
 The depth of the cell was 1.41 cm. for each of the liquids studied. Especial care was taken to have the three organic solvents as nearly anhydrous and as pure as possible.  
 The photographic strip nearest to the comparison spectrum gives the absorption of the column of acetone. The next strip in order corresponds to ethyl alcohol. The third strip pertains to methyl alcohol and the strip nearest to the numbered scale is the photographic record for distilled water.  
 Acetone absorbed all radiations between  $0.20\mu$  and  $3282.4 \text{ \AA. U.}$  and the continuous background as far as  $3302.7 \text{ \AA. U.}$   
 The most refrangible spark line transmitted by the ethyl alcohol had the wave-length  $2265.1 \text{ \AA. U.}$  This liquid transmitted all the strong ultra-violet lines, but it absorbed the continuous background from  $0.20\mu$  to about  $0.275\mu$ .  
 The methyl alcohol transmitted very faintly the strong cadmium line at  $2313.0$ , but no other radiation of
148. Acetone, Ethyl Alcohol, etc.—*Cont'd*.  
 wave-length less than  $2502.1$ . The continuous background in the ultra-violet, on the contrary, was transmitted somewhat more freely by the methyl than by the ethyl alcohol.  
 The distilled water was perfectly transparent to all the radiations in the region photographed.  
 These results show that even ethyl alcohol is not without sufficient absorption in the remote ultra-violet to make it necessary to take this factor into account when columns two or more cm. long are used.
149. Aesculine.  
 Fig. 73, pl. 19.  
 White powder. In solution colorless. Saturated.  
 Angle  $39.0'$ . Depth 0 to  $0.36$  mm.  
 No visible absorption. Intense, blue fluorescence. Absorption decreases from  $0.20\mu$  to semi-transparency about  $0.26\mu$ . Partial transparency from  $0.26\mu$  to  $0.273\mu$ . The band with which the fluorescence is probably associated extends from  $0.273\mu$  to  $0.363\mu$  with the maximum near  $0.32\mu$ . Complete transparency from this band to  $0.63\mu$  and beyond.
150. Aluminium Chloride, Calcium Bromide, and Calcium Chloride.  
 Fig. 88, pl. 22.  
 The depth of the cell was 1.41 cm. for each of the solutions studied. The photographic strip nearest to the comparison spectrum gives the absorption of the calcium bromide solution. The next strip in order corresponds to the aluminium chloride. The third strip from the comparison spectrum pertains to the calcium salt. The remaining strip shows the lack of absorption possessed by distilled water.  
 The concentrations of the aluminium chloride, calcium bromide, and calcium chloride solutions were, respectively, 2.75, 4.24, and 4.51 normal. The unit used here is the gram-molecular normal; that is, 1 liter of solution of unit concentration would contain 1 gram molecule of the anhydrous salt.  
 The aluminium chloride solution transmitted faintly all of the strongest

150. Aluminium Chloride, etc.—*Continued.*  
lines in the remote ultra-violet, but it absorbed the continuous background from  $0.20\mu$  to about  $0.288\mu$ . The calcium bromide solution transmitted nothing between  $0.20\mu$  and  $2748.7$ . The intensity of this strong cadmium line was greatly diminished. The continuous background began to be perceptible photographically at about  $0.313\mu$ .

The calcium chloride solution transmitted faintly all of the strongest lines in the remote ultra-violet, but it absorbed the continuous background from  $0.20\mu$  to about  $0.280\mu$ .

Consequently there is no very marked difference between the absorptions exerted by the two chlorides. The bromide, on the other hand, possesses much stronger absorption in the ultra-violet region of the spectrum.

151. Barium Permanganate.

The absorption is identical with that of potassium permanganate solutions, having the same concentration in the  $MnO_4$  ions. See No. 179.

152. Calcium Bromide.

See No. 150.

153. Calcium Chloride.

See No. 150.

154. Carborundum and Diamond.\*

Fig. 89, pl. 22.

Eight crystalline plates of carborundum and three of diamond were fastened to a strip of black paper in such a manner as to bridge across different parts of a long, slit-like opening in the paper. The carborundum plates varied in color from visible transparency to deep blue. The carbons were colorless. The accompanying sketch shows approximately the size, shape, relative positions, and distribution of blue of the plates. *d*, *c*, and *f* denote the diamonds. The paper strip was slid over the slit of the spectrograph, parallel to the length of this opening, and successive exposures were taken.



Fig. 7.

154. Carborundum and Diamond.—*Cont'd.*

The absorption produced by plates *a*, *b*, *c*, *d*, and *e* was first photographed, then the absorption of *f* and *g*, next that of *h* and *i*, and lastly, that of *j* and *k*. The spark and glower exposures were 75 sec. and 60 sec., respectively.

Plate *a* was uniformly colored a blue of moderate intensity. Its absorption is shown by the photographic strip, the outer boundaries of which are numbered 1 and 2. In cases where the crystals were not in contact the light passed through between them and produced narrow comparison spectra; for example, the strip between Nos. 2 and 3.

Plate *b* was almost colorless with a frosted surface. Thickness  $0.036$  mm. Its absorption spectrum is the strip between 3 and 4.

Plate *c* had about the same color as plate *a*. Thickness  $0.173$  mm. Its absorption spectrum is the strip between 5 and 6.

Plate *d* was a smooth, colorless carbon. Thickness  $0.191$  mm. Its spectrum is between 6 and 7. *c* and *d* were practically in contact. This pair of plates shows how much more transparent to ultra-violet light pure carbon is than a colorless plate of carborundum of comparable thickness. Judging by the *negative* the former transmits no light of wavelength shorter than  $2748.7 \text{ \AA}$ . U., whereas the latter absorbs everything shorter than  $0.390\mu$ .

Plate *e* had such an irregular surface that the light transmitted by it did not fall upon the sensitized film. Thickness about  $0.191$  mm. The blank between 10 and 11 is due to translation of the photographic film between the first and second settings.

Plate *f* was a diamond with irregularities running parallel to the slit. Thickness  $0.533$  mm. Spectrum between 11 and 12.

Plate *g* was a deeper blue than any of the above-mentioned crystals in the pentagon nearer plate *f*. The wide border, extending around four sides of the blue area, was practically colorless. Thickness  $0.602$  mm.

\* Kindly loaned by Mr. L. E. Jewell.

154. Carborundum and Diamond—*Cont'd.*  
Spectrum between 13 and 14. *f* and *g* contrast diamond, colorless carborundum, and blue carborundum with one another. The blank from 14 to 15 marks the second setting of the film.  
Plate *h* had a delicate, uniform, blue tint. Thickness 0.064 mm. Spectrum between 16 and 17.  
Plate *i* was a deeper blue than any of the preceding crystals. Thickness 0.345 mm. Spectrum between 18 and 19. The blank from 19 to 20 corresponds to the third setting of the photographic film.  
The center of plate *j* was as deep in color as the middle of *i* and it was also the thickest plate studied. Thickness 0.693 mm. Spectrum between 20 and 21.  
Plate *k* was of a delicate blue color of a slightly deeper hue than plates *b* and *c*, except in the corner nearer *j*. In the latter place it had about the same tint as plate *h*. Thickness 0.097 mm. Spectrum between 22 and 23.
155. Chromium Chloride.  
Fig. 79, pl. 20.  
In solution very dark green, green. Saturated.  
Angle 50.7'. Depth, from nearly 0 to 0.46 mm.  
Strong absorption in the violet, blue, orange, and red.  
Absorption was complete from 0.20 $\mu$  to 0.303 $\mu$ . The boundary of the ultra-violet band curved around from 0.303 $\mu$  to 0.328 $\mu$  as the thickness of absorbing layer increased from its least to its greatest value. Semi-transparency from 0.328 $\mu$  to 0.380 $\mu$ . A wide, round band, with its maximum near 0.438 $\mu$ , absorbed from 0.380 $\mu$  to 0.498 $\mu$ . This is followed by fairly complete transmission from 0.498 $\mu$  to 0.555 $\mu$ . The orange and red region of absorption commenced at about 0.555 $\mu$ .
156. Cobalt Chloride.  
Fig. 78, pl. 20.  
In solution red, rose-pink.  
351.9 g. of anhydrous salt per liter (2.71 normal).
156. Cobalt Chloride—*Continued.*  
Angle 58.5'. Depth 0.53 to 1.07 mm.  
One absorption band in the blue-green and another in the deep red.\* Absorption was complete from 0.20 $\mu$  to about 0.248 $\mu$ . The solution was quite transparent from 0.25 $\mu$  to about 0.495 $\mu$ . An absorption band, with its maximum near 0.520 $\mu$ , extended from 0.497 $\mu$  to 0.542 $\mu$ . Transparent from the boundary of this band as far as the deep red.
157. Cobalt Chloride and Aluminium Chloride.  
Fig. 95, pl. 24.  
The plane-parallel cell was kept at the constant depth of 1.41 cm.  
The successive solutions were made up in the following manner: First, a chosen volume of the mother-solution of cobalt chloride was run from a burette or pipette into a measuring flask. Next, a certain amount of the mother-solution of aluminium chloride was run into the same flask and mixed with the solution of the cobalt salt. Finally, distilled water was added to the mixture until the resulting solution filled up the measuring flask to its calibration mark. Of course, all the usual precautions necessary to avoid errors due to changes in volume on mixing and to lack of homogeneity were taken. Each solution of the series was made up to the same volume and contained the same amount of cobalt chloride. On the other hand, the mass of the dehydrating agent present changed from one solution to the next.  
The photographic strips nearest to the numbered scale and to the comparison spectrum correspond, respectively, to the solutions which contained the least and greatest amounts of the aluminium salt. The intervening strips succeed one another in the order of increasing percentages of aluminium chloride. The constant concentration of the cobalt chloride in the solutions was 0.271 normal. The concentrations of the aluminium chloride in the several

\* For exhaustive details see "Hydrates in Aqueous Solution," etc. Harry C. Jones, Publication No. 60 of the Carnegie Institution of Washington.



157. Cobalt Chloride, etc.—*Continued.*

solutions of the series were 0.000, 1.118, 1.394, 1.676, 1.781, 1.887, 2.096, and 2.459 normal.

The solution which contained no dehydrating agent only absorbed the continuous background from  $0.20\mu$  to  $0.231\mu$ . The band in the blue-green extended from  $0.503\mu$  to about  $0.530\mu$ .

The solution of concentration 2.096, in the aluminium chloride, absorbed the continuous background from  $0.20\mu$  to  $0.288\mu$ . The band in the blue-green extended from  $0.485\mu$  to  $0.555\mu$ .

The absorption in the yellow and orange is brought out clearly by the photographic strip adjacent to the comparison spectrum. The changes which the bands in the orange and red undergo when the amount of dehydrating agent in the solutions is increased are pronounced and interesting, but they are too complicated to admit of discussion in this place.\* Similar changes are brought about by other dehydrating agents, such as calcium chloride, for example.

Figure 95 illustrates the fact that the absorption bands of a colored salt, so-called, can be widened by the addition of suitable colorless salts as well as by simple increase in concentration.

## 158. Cobalt Chloride in Acetone.

Fig. 90, pl. 23, and fig. 94, pl. 24.

Fig. 90 shows the changes in the positions of the centers of the regions of absorption and transmission of cobalt chloride produced by varying the solvent. The depth of the cell was 2.40 cm. Counting from the comparison spectrum towards the opposite side of the spectrogram, the four photographic strips correspond to solutions of anhydrous cobalt chloride in water, in absolute methyl alcohol, in absolute ethyl alcohol, and in anhydrous acetone, respectively.

The aqueous solution was rosy red. The methyl solution was purple. The color of the ethyl solution was blue with a slight reddish tinge. The solution in acetone was blue with a

158. Cobalt Chloride in Acetone—*Cont'd.*

slight greenish tinge. The concentrations of the solutions, in the order named, were, respectively, 0.325, 0.099, 0.097, and 0.010 normal.

The aqueous solution absorbed practically all radiations from  $0.20\mu$  to  $0.275\mu$ . The blue-green band absorbed the region between  $0.45\mu$  and  $0.55\mu$ .

The solution having methyl alcohol for solvent absorbed all of the ultra-violet from  $0.20\mu$  to near  $0.39\mu$ . It then transmitted from  $0.39\mu$  to  $0.495\mu$ . The next absorption band extended from  $0.495\mu$  to  $0.56\mu$ . The faintness of the associated photographic strip shows the presence of appreciable absorption in the yellow.

Both the ultra-violet absorption and the adjoining region of transmission were very nearly the same for the solution in ethyl alcohol as for that in methyl alcohol. On the contrary, the third strip gives no indication of return to transparency in the yellow of the band which absorbed all of the green.

The acetone solution transmitted the region between about  $0.38\mu$  and  $0.56\mu$ , but absorbed all the other radiations which could affect the Seed film.

The phenomena in the visible spectrum were brought out very clearly by photographing with a Cramer "Trichromatic" plate. The depth of the cell was decreased to 2.00 cm.

The aqueous solution transmitted from beyond the shorter wavelength end of the plate to  $0.46\mu$  and again from  $0.543\mu$  to beyond  $0.625\mu$  at the other end of the plate.

The solution in methyl alcohol transmitted from  $0.387\mu$  to  $0.495\mu$  and again from  $0.548\mu$  to beyond  $0.625\mu$ . The intensity of the transmitted light, in the yellow and orange, however, was not as great for the methyl as for the aqueous solution.

The solution in ethyl alcohol only transmitted from  $0.385\mu$  to  $0.497\mu$ .

The solution in acetone only transmitted from  $0.373\mu$  to  $0.560\mu$ .

\*For exhaustive details see "Hydrates in Aqueous Solution," etc. Harry C. Jones, Publication No. 60 of the Carnegie Institution of Washington.

158. Cobalt Chloride in Acetone—*Cont'd.*

It is thus seen that the photographic center of the band of absorption in the green was displaced by about 200 Angström units as the solvent was changed from water to methyl alcohol. A still greater displacement was produced by changing from the one alcohol to the other, the concentrations of the two solutions being very nearly equal.

The empirical data given above serve to illustrate\* the general fact that the position and character of a given region of absorption or of transmission of a chosen colored salt can be varied, in general, over wide ranges by suitable changes in the solvent used.

Fig. 94 shows the way in which the limits of absorption change when water is added to solutions of anhydrous cobalt chloride dissolved in absolute acetone. The depth of the cell was 2 cm. The solutions were made up in the following manner: A certain arbitrary volume of water was poured into a measuring flask and then the flask was filled up to its calibration mark by running into it from a burette the requisite amount of a mother-solution composed of anhydrous cobalt chloride and absolute acetone. When water is gradually added to such a mother-solution the resulting liquid changes by degrees from deep blue through light blue and then through an almost colorless condition to faint pink.

The percentages by volume of the water in the solutions under consideration were, 0, 2, 4, 6, 8, 10, and 12. The concentration of the mother-solution was 0.015 normal.

The photographic strip nearest to the comparison spectrum corresponds to the solution which was anhydrous. The next strip pertains to the solution which contained 2 per cent of water, and so on, across the entire spectrogram. The mother-solution absorbed completely all radiations between  $0.20\mu$  and  $0.333\mu$ . The continuous background was very much weakened as far as about  $0.361\mu$ . The solution transmitted freely

158. Cobalt Chloride in Acetone—*Cont'd.*

from this wave-length to near  $0.552\mu$ . A strong absorption band commenced at  $0.552\mu$  and extended into the red.

The photographic strip pertaining to the solution which contained the smallest measured amount of water transmitted from  $0.333\mu$  to about  $0.566\mu$ . The change in absorption due to the addition of water to the anhydrous mother-solution is, therefore, more noticeable in the ultra-violet than in the yellow. The photographic boundary of the ultra-violet absorption band changed but little, as the percentage of water present in the solutions increased from 2 to 12, and this is due to the intense ultra-violet absorption of the pure acetone. (*See* No. 148.) On the other hand, acetone possesses no absorption band in the visible spectrum, and hence the limits of transmission in the green and yellow, as shown by the several strips of the spectrogram, represent correctly the changes in absorption consequent upon the addition of successive increments of water.

## 159. Cobalt Chloride in Ethyl Alcohol.

*See* No. 158.

## 160. Cobalt Chloride in Methyl Alcohol.

*See* No. 158.

## 161. Cobalt Glass.

Fig. 85, pl. 21.

A plane-parallel sheet of ordinary blue cobalt-glass was ground to the form of a wedge and then polished. A prism of colorless glass was attached at the sides to the cobalt prism with its refracting edge parallel to that of the colored glass. The two wedges were in contact over their hypotenuse planes, and hence the outer plane surfaces were nearly parallel. The object in using the colorless glass wedge was, obviously, to correct for the dispersion of the cobalt-glass prism. The lack of agreement between the contiguous edges of the two photographic strips shows that the angle of the colorless prism ought to have been at least twice as large as that of the blue prism. The angle of the cobalt-

\* *See* also No. 165.

161. Cobalt Glass—*Continued*.

glass wedge was approximately  $9^\circ$ . The compound system absorbed all the ultra-violet from  $0.20\mu$  to  $0.325\mu$ . The boundary of the ultra-violet band does not curve or slant very much with reference to the long axis of the spectrogram because of the absorption of the colorless glass in this region of the spectrum. The cobalt-glass transmits from about  $0.327\mu$  to  $0.497\mu$ . Beginning at  $0.497\mu$  a region of absorption extends into the red. The most refrangible band in this region has its maximum near  $0.52\mu$ . The minimum of absorption between the band just mentioned and the less refrangible, neighboring band is at wavelength  $0.560\mu$ . The band in the orange extended into the red beyond the field of view of the spectrograph. These results were tested by using a red-sensitive photographic plate.

## 162. Cobalt Sulphate.

Similar to fig. 78, pl. 20.

Reddish crystals. In solution red, salmon pink.

Saturated.

Angle about  $6^\circ$ . Depth 0 to about 3.2 mm.

Rather weak absorption in the blue-green. All of the strongest ultra-violet lines were transmitted. The continuous background was absorbed from  $0.20\mu$  to about  $0.255\mu$ . The band in the blue-green extended from  $0.505\mu$  to  $0.525\mu$  with its center near  $0.515\mu$ .

## 163. Copper Chloride.

Fig. 77, pl. 20.

Dark-green crystals. In solution dark green, yellowish green.

534.7 g. of anhydrous salt per liter (3.98 normal).

Angle  $19.5'$ . Depth nearly 0 to 0.18 mm.

Intense absorption in the red. The solution was remarkable for its strong absorption of the ultra-violet radiations. Absorption was complete from  $0.20\mu$  to  $0.32\mu$  at the thinnest part of the wedge. The end of this band curved around from  $0.32\mu$  to  $0.40\mu$ . Transmission was complete from about  $0.40\mu$  to the orange.

## 164. Copper Chloride and Calcium Chloride.

Fig. 92, pl. 23.

The plane-parallel cell was kept at the constant depth of 1.41 cm. The several solutions were made up as explained under No. 157, which see. The photographic strips nearest to the numbered scale and to the comparison spectrum correspond, respectively, to the solutions which contained the least and greatest amounts of the calcium salt. The intervening strips succeed one another in the order of increasing percentages of calcium chloride. The constant concentration of the copper chloride in the solutions was 0.398 normal. The concentrations of the calcium chloride in the several solutions of the series were 0.000, 0.271, 0.541, 0.812, 1.082, 1.353, 1.624, 1.894, 2.165, 2.435, 2.706, 2.977, 3.247, 3.518, 3.788, and 4.041 normal. The addition of calcium chloride to an aqueous solution of copper chloride changes the color of the latter from clear blue, through green, to yellowish green, due to the presence of an absorption band in the red\* and to the encroaching of the ultra-violet band upon the violet and blue.

The solution which contained only copper chloride absorbed all radiations from  $0.20\mu$  to about  $0.361\mu$ . The solution which contained the greatest amount of the dehydrating agent absorbed all radiations from  $0.20\mu$  to about  $0.509\mu$ . Hence, the ultra-violet region of absorption widened by about 1480 Ångström units when the concentration of the calcium chloride was increased from 0.000 to 4.041 normal. The spectrogram shows clearly how the successive increments of absorption decreased as the concentration of the calcium salt increased in arithmetical progression. Other dehydrating agents, such as aluminium chloride, for example, produce similar changes in the limits of absorption.

\*For exhaustive details see "Hydrates in Aqueous Solution," etc. Harry C. Jones, Publication No. 60 of the Carnegie Institution of Washington.

## 165. Copper Chloride in Acetone.

Fig. 91, pl. 23, and fig. 93, pl. 24.

Fig. 91 shows the changes in the positions of the ends of the regions of absorption and transmission of copper chloride produced by varying the solvent. The depth of the cell was 1.50 cm. Counting from the comparison spectrum towards the opposite side of the spectrogram, the four photographic strips correspond to solutions of anhydrous copper chloride in absolute acetone, in absolute ethyl alcohol, in anhydrous methyl alcohol, and in water, respectively. The acetone solution was brownish yellow. The ethyl solution was dark green. The color of the methyl solution was yellowish green. The aqueous solution was blue. The concentrations of the solutions, in the order named, were, respectively, 0.022, 0.321, 0.283, and 0.795 normal. The aqueous solution absorbed all radiations from  $0.20\mu$  to  $0.387\mu$  and from  $0.588\mu$  into the red.

The solution having methyl alcohol for solvent absorbed all of the ultra-violet from  $0.20\mu$  to near  $0.462\mu$ . It transmitted from  $0.462\mu$  to beyond the region of photographic sensibility of the Seed films.

The solution in ethyl alcohol absorbed from  $0.20\mu$  to about  $0.515\mu$  and again from  $0.59\mu$  into the red.

The acetone solution absorbed from  $0.20\mu$  to near  $0.510\mu$ . It transmitted from  $0.510\mu$  to beyond the region of sensibility of the film used.

These results were supplemented by the aid of a Cramer "Trichromatic" plate. A bluish-green, aqueous solution of concentration 1.590 normal was substituted for the one referred to above. The depth of cell and the concentrations of the three remaining solutions were unaltered. This photograph showed that the new aqueous solution transmitted from  $0.434\mu$  to  $0.588\mu$ , the methyl solution from  $0.462\mu$  to beyond  $0.625\mu$ , the ethyl solution from  $0.513\mu$  to  $0.604\mu$ , and the acetone solution from  $0.510\mu$  to beyond  $0.625\mu$ .

165. Copper Chloride in Acetone—*Cont'd.*

The exposures for the Seed film and the Cramer plate were, respectively, 1.5 and 2 minutes long.

Fig. 93 shows the way in which the limits of absorption change when water is added to solutions of anhydrous copper chloride dissolved in absolute acetone. The depth of the cell was 2 cm. The solutions were made up as explained under No. 158, which see.

The percentages by volume of the water in the solutions under consideration were 0, 1, 2, 3, 4, 6, and 8. The concentration of the mother-solution was 0.022 normal.

The photographic strip nearest to the comparison spectrum corresponds to the solution which was anhydrous. The next strip pertains to the solution which contained 1 per cent of water, etc., across the entire spectrogram. The mother-solution absorbed completely all radiations from  $0.20\mu$  to  $0.517\mu$ . The next four solutions had a region of transmission the center of which was at  $0.436\mu$ . This region was followed by an absorption band whose middle was displaced towards the ultra-violet as the amount of water in the solutions was increased. For the 1 and 2 per cent solutions the center of the absorption band had the approximate wave-lengths  $0.478\mu$  and  $0.475\mu$ , respectively. The solution which contained 8 per cent of water absorbed all radiations from  $0.20\mu$  to about  $0.393\mu$  and transmitted from this wave-length to beyond  $0.62\mu$ .

## 166. Copper Chloride in Ethyl Alcohol.

See No. 165.

## 167. Copper Chloride in Methyl Alcohol.

See No. 165.

## 168. Diamond.

See No. 154.

## 169. Erbium Chloride.\*

Fig. 101, pl. 26. In solution very faint pink.

Concentrated (filtered).

The solution was poured into a quartz cell, the ends of which were plane and parallel. The cell was successively adjusted to the following

\* A specimen from the collection of the late Prof. Henry A. Rowland.

169. Erbium Chloride—*Continued.*

depths, viz: 0.83, 1.13, 1.43, 1.73, 2.03, 2.33, 2.63, and 2.93 cm. In other words, the thickness of the absorbing layer was increased by 3 mm. between the successive photographic exposures. As has been often remarked by other observers, the solution in question has a very large number of remarkably narrow absorption bands.

For the depth of 0.83 cm. all of the ultra-violet is absorbed from  $0.20\mu$  to the cadmium line at 2880.9, while for the depth of 2.93 cm. transmission begins near  $0.300\mu$ . The wave-lengths of the maxima of the absorption bands, and the essential characteristics of the bands, as obtained directly from the original negative, are as follows:  $0.325\mu$ ,  $0.350\mu$ , strong with a broad penumbra on both sides;  $0.3555\mu$ , faint;  $0.3645\mu$ , strong;  $0.3662\mu$ , faint companion of the last;  $0.3766\mu$ , narrow and faint;  $0.3792\mu$ , strong and sharp;  $0.3875\mu$ , faint, diffuse band shading off gradually towards the red;  $0.405\mu$ , weak and sharp;  $0.4075\mu$ , weak;  $0.416\mu$ , faint, diffuse band shading off towards the red;  $0.419\mu$ , faint;  $0.422\mu$ , faint and narrow;  $0.427\mu$ , extremely faint and diffuse band;  $0.4425\mu$ , faint;  $0.450\mu$ , comparatively strong and narrow with a very faint companion at the more refrangible side and with a broad, hazy band near the opposite edge;  $0.4675\mu$ , very faint;  $0.4725\mu$ , very faint and diffuse;  $0.480\mu$ , extremely faint;  $0.485\mu$ , weak;  $0.4875\mu$ , comparatively strong and narrow;  $0.491\mu$ , wide, hazy band shading off towards the red;  $0.5186\mu$ , weak and narrow;  $0.5205\mu$ , narrow;  $0.5235\mu$ , strong and narrow;  $0.5365\mu$ , weak and broad; and  $0.5413\mu$ , weak with a broad, diffuse companion on the side nearest to the red.

## 170. Ethyl Alcohol.

*See* No. 148.

## 171. Glycerine.

A plane-parallel layer of glycerine 13.5 mm. deep absorbed all light of wave-length less than  $0.25\mu$  and it produced a general weakening

171. Glycerine—*Continued.*

of the continuous background as far as about  $0.33\mu$ . The exposure lasted for 1.5 minutes.

## 172. Litmus.

*Figs. 83 and 84, pl. 21.*

In solution blue and red for the neutral (or alkaline) and acid conditions, respectively.

Saturated.

Angle, about  $6^\circ$  for both cases.

Depth 0 to 3.2 mm., approximately, for fig. 83.

The absorption of the blue solution is suggested by fig. 83. Absorption was practically complete from  $0.20\mu$  to about  $0.28\mu$ . From this wave-length the absorption band followed a gentle slope to about  $0.42\mu$  for the greatest depth of solution. A region of partial transparency extended from  $0.42\mu$  to near  $0.496\mu$ . A band of absorption began at  $0.496\mu$  and had its maximum approximately at  $0.531\mu$ . The spectrogram indicates the existence of intense absorption in the orange and red.

Fig. 84 gives the photographic record obtained with an acid solution of litmus. This solution absorbed the greater part of the ultra-violet region just as the neutral solution did. On the other hand, the acid solution exerted general absorption in the violet and blue, whereas the neutral solution, of the same depth, transmitted the light of these colors. The maximum of the band in the green was at  $0.515\mu$  for the red solution. The displacement of this maximum from  $0.531\mu$  to  $0.515\mu$  was probably exaggerated by the variations of sensibility of the photographic films for radiations of different wave-lengths. Fig. 84 recorded only weak absorption in the yellow-orange. Red was transmitted.

## 173. Methyl Alcohol.

*See* No. 148.

## 174. Neodymium Ammonium Nitrate.

*Figs. 96, 97, and 98, pl. 25.*

Pink crystals. In solution pink.

Concentrated (filtered).

For fig. 96 the solution was poured into a quartz cell the ends of

174. Neodymium Ammonium Nitrate—  
*Continued.*

which were plane and parallel. The cell was successively adjusted to the following depths, viz: 0.53, 0.83, 1.13, 1.43, 1.73, 2.03, 2.33, and 2.63 cm. In other words, the thickness of the absorbing layer was increased by 3 mm. between the successive photographic exposures. As has been often remarked by other observers, the solution in question has a large number of unusually narrow absorption bands, some of which are very intense and persistent.

For the depth of 0.53 cm. all of the ultra-violet is absorbed from 0.20 $\mu$  to the zinc line at 3302.7, while for the depth of 2.63 cm. only very faint transmission obtains in the immediate vicinity of 3407.7 Å. U. The general characteristics of the most intense bands can be readily seen by referring to fig. 96, hence it will suffice to give the approximate wave-lengths of the absorption bands which were recorded by the original negative.

The centers of the bands were at 0.347 $\mu$ , 0.350 $\mu$ , 0.355 $\mu$ , 0.381 $\mu$ , very faint; 0.418 $\mu$ , faint; 0.4275 $\mu$ , sharp; 0.433 $\mu$ , very faint; 0.4437 $\mu$ , diffuse; 0.461 $\mu$ , faint and diffuse; 0.4695 $\mu$ , 0.4755 $\mu$ , faint; 0.4823 $\mu$ , 0.5087 $\mu$ , 0.5112 $\mu$ , with a hazy boundary at the less refrangible side; 0.520 $\mu$ , 0.5225 $\mu$ , broad and intense; 0.5324 $\mu$ , faint; 0.5775 $\mu$ , broad and intense, and 0.5925 $\mu$ , faint and diffuse.

Fig. 97 shows the absorption of the same solution when placed in the wedge-shaped cell. The angle of the liquid wedge was 1° 18' and the depth increased linearly from 0.71 mm. to 1.24 mm. Except for the transmission of the strong metallic lines at 2558.0, 2573.1, and 2748.7, the ultra-violet absorption is practically complete as far as 0.3250 $\mu$ . The negative for fig. 97 recorded very faintly all of the absorption bands given above except the ones at 0.347 $\mu$ , 0.350 $\mu$ , 0.381 $\mu$ , 0.418 $\mu$ , 0.461 $\mu$ , and 0.5324 $\mu$ .

174. Neodymium Ammonium Nitrate—  
*Continued.*

The angle of the cell was 39' for fig. 98, so that the thickness of the absorbing layer varied from about 0 to 0.36 mm. Absorption was complete from 0.20 $\mu$  to 0.237 $\mu$ . The boundary of this region of absorption curved around rather abruptly from 0.237 $\mu$  to 0.250 $\mu$  as the depth of solution increased from its least to its greatest value. Transmission by the deepest part of the liquid wedge was weakened somewhat from 0.277 $\mu$  to 0.308 $\mu$ . Only the intense absorption band at wave-length 5225 Å. U. was recorded by the negative.

## 175. Nickel Nitrate.

Fig. 81, pl. 21.

Green crystals. In solution green, light green.

Saturated.

Angle, about 6°. Depth 0 to 3.2 mm., approximately.

Strong absorption in the orange and red, also weaker absorption in the extreme violet. The absorption was nearly complete from 0.20 $\mu$  to about 0.312 $\mu$ . The end of this region of absorption curved around from 0.312 $\mu$  to 0.326 $\mu$  with increasing depth of solution. Unusual transparency from 0.326 $\mu$  to 0.374 $\mu$ . A symmetrical absorption band, with its maximum at 0.391 $\mu$ , extended from 0.374 $\mu$  to 0.408 $\mu$ . Transmission was complete from this point as far as the absorption band in the orange. The sloping end of the spectrogram calls attention to absorption in the orange.

## 176. Nickel Sulphate.

Fig. 82, pl. 21.

Green crystals. In solution green, pale green.

Saturated.

Angle, about 6°. Greatest depth, 3.2 mm., approximately. Absorption in the extreme violet, orange, and red. Using the faint comparison spectrum as a standard of comparison, it becomes evident that the solution was remarkably transparent to the ultra-violet radiations from 0.226 $\mu$  to about 0.365 $\mu$ . A symmetrical absorption band,

176. Nickel Sulphate—*Continued.*

with its maximum at  $0.391\mu$ , extended from  $0.367\mu$  to  $0.415\mu$ . Transmission was complete from this point as far as the absorption band in the orange. A comparison of figs. 81 and 82 is very suggestive. Both spectrograms show the same band at wave-length  $0.391\mu$ , but the ultra-violet absorption exerted by the nitrate is entirely different from that shown by the sulphate.

## 177. Picric Acid.

Fig. 86, pl. 22.

Yellow crystals with greenish hue.

In solution yellow, pale yellow.

Concentration unknown.

Angle  $50.7'$ . Depth 0 to  $0.46$  mm.

Hazy band in the violet extending into the ultra-violet. Absorption decreased gradually from  $0.20\mu$  to partial transparency at  $0.275\mu$ . Semi-transparency from  $0.275\mu$  to  $0.300\mu$ . A band of absorption, with hazy contour, extended from about  $0.300\mu$  to  $0.400\mu$ , its maximum being near  $0.35\mu$ .

## 178. Potassium Chromate.

Fig. 80, pl. 20.

Yellow crystals. In solution yellow, faint yellow.

Very dilute.

Angle  $50.7'$ . Change in depth  $0.46$  mm.

Absorption in the extreme violet extending into the ultra-violet. The most refrangible absorption band only extends from beyond  $0.20\mu$  to  $0.226\mu$ . The solution is noticeably transparent to all radiations from  $2265.1 \text{ \AA. U.}$  to  $2321.2 \text{ \AA. U.}$ , inclusive of these limits. An intense band extends from  $0.227\mu$  to  $0.300\mu$ . This is followed by a region of almost complete transparency, the middle of which is near  $0.316\mu$ . A strong band of absorption extends from  $0.332\mu$  to  $0.406\mu$  with its maximum at  $0.369\mu$ .

## 179. Potassium Permanganate.

Figs. 74 and 75, pl. 19.

Grayish-brown crystals with violet reflex. In solution deep violet, violet.

179. Potassium Permanganate—*Continued.*

16.67 g. per liter.

Angle  $27.3'$ . Depth 0 to  $0.25$  mm.

Five distinct bands clearly visible in the green with a very faint companion on the blue side. The central band of the five is a little more intense than its less refrangible neighbor. Light from the spark decomposes the potassium permanganate so rapidly, with the formation of innumerable small bubbles, that the exposures had to be made as follows: 1st. Expose to spark for 25 seconds. 2d. Remove cell from spectrograph and clean away the bubbles. 3d. Replace the cell and make another exposure for 25 seconds, etc., three times for each distinct strip of the spectrogram. The absorption at  $0.20\mu$  is weak and decreases to transparency near  $0.25\mu$ . Unusual transparency from  $0.25\mu$  to  $0.29\mu$ . This fact is brought out in a half-dozen spectrograms of the region. A band of absorption extends roughly from  $0.29\mu$  to  $0.36\mu$  with its maximum at the center. The transparency increases to completeness and continues to  $0.483\mu$ . The wave-lengths of the 7 photographic bands are  $0.457\mu$ ,  $0.472\mu$ ,  $0.488\mu$ ,  $0.505\mu$ ,  $0.525\mu$ ,  $0.545\mu$ , and  $0.570\mu$ . (Only 5 bands show on the complete spectrogram.) In decreasing order of intensity the three strongest bands are  $0.525\mu$ ,  $0.505\mu$  and  $0.545\mu$ .

An effort was made to detect the 8 bands given by Formánek,\* but the conditions were not favorable to recording more than seven bands. Formánek's wave-lengths are "571.0, 547.3 (Hauptstreifen), 525.6, 505.4, 487.0, 470.7, 454.4, and 439.5."

The negative for fig. 75, pl. 19, shows the seven bands. The solution was practically saturated since it contained 50 grams per liter at room temperature. Here the ultra-violet absorption extends as far as  $0.39\mu$ . For concentrations from  $16.67$  to 50 grams per liter, and for

\* See J. Formánek, "Die qualitative Spectralanalyse anorganischer Körper," p. 59.

179. Potassium Permanganate—*Continued.*  
the method used, the bands do not shift at all.\* Trichromatic plates were used to see if any photographic bands less refrangible than  $0.570\mu$  could be recorded. No evidence of the existence of such bands was presented.
180. Praseodymium Ammonium Nitrate.  
Fig. 100, pl. 26.  
Yellowish-green crystals. In solution yellowish green.  
Concentrated (filtered).  
The solution was poured into a quartz cell, the ends of which were plane and parallel. The cell was successively adjusted to the following depths, viz: 0.73, 1.03, 1.33, 1.63, 1.93, 2.23, 2.53, and 2.83 cm. In other words, the thickness of the absorbing layer was increased by 3 mm. between the successive photographic exposures.  
The solution is remarkable for the comparative narrowness and great intensity of its absorption bands. Absorption was complete from  $0.20\mu$  to about  $0.333\mu$  and  $0.343\mu$ , respectively, for the least and greatest depths of solution investigated. The centers of the four intense bands which fell within the region of sensitivity of the Seed emulsion were at wave-lengths  $0.4445\mu$ ,  $0.4685\mu$ ,  $0.4820\mu$ , and  $0.590\mu$ . The least refrangible side of the band at  $0.590\mu$  does not appear in fig. 100 because the band came very near the limit of sensibility of the photographic film employed.
181. Sodium Bichromate.  
Suggested by fig. 14, pl. 4.  
Orange-red crystals. In solution yellow, pale yellow.  
Very dilute solution.  
Angle  $50.7'$ . Depth 0 to 0.46 mm.
181. Sodium Bichromate—*Continued.*  
The spectrogram differs from fig. 14 in having the ultra-violet absorption curve displaced bodily towards the region of the shortest wave-lengths. Absorption was practically complete from  $0.20\mu$  to about  $0.27\mu$ , for all depths. At the thickest part of the liquid wedge absorption was complete from  $0.20\mu$  to  $0.40\mu$ , but both the photographic strip adjacent to the comparison spectrum and the one in the middle of the spectrogram recorded a comparatively narrow band of semi-transparency, the center and maximum of which was near  $0.318\mu$ . This was followed by a strong, round absorption band whose maximum was at  $0.36\mu$ . In other words, there were two round, ultra-violet bands of absorption which coalesced at the wave-length  $0.318\mu$ . Transmission was complete from  $0.40\mu$  to  $0.63\mu$ .
182. Sodium Nitroprussid.  
Fig. 76, pl. 19.  
Garnet crystals. In solution reddish brown, light brown.  
Saturated.  
Angle  $1^\circ 45'$ . Depth 0 to 0.96 mm.  
Weak absorption in violet. Light from the spark decomposes the solution at the very beginning of illumination so that the method used for photographing the ultra-violet absorption of the permanganates was not applicable. This difficulty was not overcome. Absorption decreases to about  $0.38\mu$ , then increases to a weak maximum near  $0.396\mu$ , and finally decreases to transparency at  $0.428\mu$ . No selective absorption from  $0.43\mu$  to  $0.62\mu$ .
183. Water. See No. 148.

\*See H. Kayser, "Handbuch der Spectroscopie," v. iii, p. 415.



## ALPHABETICAL LIST OF ABSORBING MEDIA.

	Page	No.	Pl.	Fig.		Page	No.	Pl.	Fig.
Acetone.....	46	148	22	87	Coccine B.....	23	20	.....	.....
Acid Brown.....	27	42	.....	.....	Columbia Fast Scarlet 4 B.....	45	140	.....	.....
Acid Green, conc'.....	35	86	12	46	Columbia Yellow.....	43	129	3	13
Acid Magenta S.....	43	133	.....	.....	Congo Brown G.....	33	77	9	{ 35 36
Acid Rosamine A.....	38	106	5	19	Congo Brown R.....	33	78	9	35
Aesculine.....	46	149	19	73	Congo Corinth.....	32	71	.....	.....
Alizarine Blue S.....	41	120	7	28	Congo Corinth G.....	30	60	6	23
Alizarine Brown.....	41	118	.....	.....	Congo Orange G.....	29	56	9	33
Alizarine Green B.....	42	128	.....	.....	Congo Orange R.....	31	63	.....	.....
Alizarine Orange. (Powder 80%)	44	134	6	24	Congo Red.....	30	59	.....	.....
Alizarine Red No. 1, 40%.....	44	135	.....	.....	Congo Rubine.....	30	61	.....	.....
Alizarine Red S.....	41	119	4	14	Copper Chloride.....	51	163	20	77
Alkali Blue 6 B.....	37	97	18	72	Copper Chloride and Calcium Chloride.....	51	164	23	92
Aluminium Chloride.....	46	150	22	88	Copper Chloride in Acetone....	52	165	{ 23 24	{ 91 93
Amidonaphtholdisulphonic Acid H.....	21	1	1	1	Copper Chloride in Ethyl Alcohol.	52	166	{ 23 24	{ 91 93
Anthracene Red.....	31	62	.....	.....	Copper Chloride in Methyl } Alcohol.....	52	167	{ 23 24	{ 91 93
Anthracene Yellow C.....	29	53	.....	.....	Coralline Red.....	37	100	13	49
Auramine O.....	34	82	11	43	Cresotine Yellow G.....	30	58	.....	.....
Aurantia.....	21	8	10	39	Crystal Ponceau 6 R.....	23	18	.....	.....
Aurophosphine 4 G.....	44	136	12	45	Crystal Violet.....	35	90	.....	.....
Azo Acid Yellow.....	25	31	.....	.....	Curcumeine.....	25	30	3	12
Azo Blue.....	32	72	.....	.....	Curcumeine S.....	34	81	10	37
Azo Coccine 2 R.....	23	14	2	9	Cyanosine.....	40	113	5	18
Azo Rubine S.....	26	35	.....	.....	Dahlia.....	35	89	18	69
Azo Yellow, conc'.....	25	31	.....	.....	Deltapurpurine 5 B.....	31	66	.....	.....
Barium Permanganate.....	47	151	19	{ 74 75	Diamine Black B O.....	33	73	.....	.....
Benzoazurine.....	33	75	.....	.....	Diamine Green B.....	33	76	.....	.....
Benzopurpurine B.....	31	65	.....	.....	Diamine Red B.....	31	66	.....	.....
Benzopurpurine 6 B.....	31	64	.....	.....	Diamine Red 3 B.....	32	68	16	61
Benzopurpurine 10 B.....	33	74	6	22	Diamond.....	52	168	22	89
Biebrich Scarlet.....	28	49	.....	.....	Dianil Orange G.....	45	141	9	34
Bismarck Brown.....	29	54	2	7	Dianil Yellow R.....	27	40	.....	.....
Blue Black.....	29	52	.....	.....	Emerald Green.....	34	84	.....	.....
Bordeaux B.....	23	19	.....	.....	Emin Red.....	24	23	8	29
Brilliant Congo R.....	32	67	.....	.....	Eosamine B.....	24	21	13	52
Brilliant Croceine, blue shade..	44	137	.....	.....	Eosine à l'alcool.....	39	109	5	17
Brilliant Orange G.....	23	15	8	31	Eosine, bluish.....	40	111	.....	.....
Brilliant Purpurine 10 B.....	44	138	.....	.....	Eosine, yellowish.....	39	108	15	58
Brilliant Purpurine R.....	32	69	7	26	Erbium Chloride.....	52	169	26	101
Calcium Bromide.....	47	152	22	88	Erika B.....	24	22	15	57
Calcium Chloride.....	47	153	22	88	Erythrosine.....	40	112	15	59
Carborundum.....	47	154	22	89	Ethyl Alcohol.....	53	170	22	87
Carthamin.....	44	139	.....	.....	Ethyl Violet.....	36	91	16	64
China Blue.....	37	99	18	71	Fast Acid Violet A 2 R.....	38	105	.....	.....
Chromium Chloride.....	48	155	20	79	Fast Acid Violet B.....	38	104	16	63
Chromotrope 6 B.....	22	13	2	8	Fast Brown 3 B.....	26	38	.....	.....
Chrysamine G.....	30	57	.....	.....	Fast Green O.....	34	79	.....	.....
Chrysoïdine.....	22	12	2	7	Fast Red A.....	26	34	7	27
Cloth Red G.....	28	45	7	25	Fast Red, extra.....	26	36	.....	.....
Cloth Red 3 G A.....	28	47	3	11	Fast Yellow.....	22	9	.....	.....
Cloth Red O.....	28	46	6	21	Fluorescence.....	45	142	.....	.....
Cobalt Chloride.....	48	156	20	78	Fuchsine.....	35	87	12	48
Cobalt Chloride and Aluminium Chloride.....	48	157	24	95	Fuchsine S.....	36	95	14	53
Cobalt Chloride in Acetone....	49	158	{ 23 24	{ 90 94	Galleine.....	40	116	.....	.....
Cobalt Chloride in Ethyl Alcohol.	50	159	{ 23 24	{ 90 94	Glycerine.....	53	171	.....	.....
Cobalt Chloride in Methyl Alcohol	50	160	{ 23 24	{ 90 94	Guinea Carmine B.....	45	143	.....	.....
Cobalt Glass.....	50	161	21	85	Heliotrope 2 B.....	42	124	17	68
Cobalt Sulphate.....	51	162	.....	.....	Indigo Carmine, dry.....	43	132	.....	.....
					Janus Green.....	24	24	.....	.....

ALPHABETICAL LIST OF ABSORBING MEDIA.—*Continued.*

	Page	No.	Pl.	Fig.		Page	No.	Pl.	Fig.
Janus Red B.....	28	44	.....	.....	Phosphine .....	41	117	8	32
Light Green F S.....	35	85	.....	.....	Picric Acid .....	55	177	22	86
Litmus .....	53	172	21	{ 83 84	Ponceau B O, extra.....	27	43	.....	.....
Malachite Green.....	34	83	.....	.....	Ponceau 2 G.....	22	11	2	6
Metanil Yellow.....	25	32	10	40	Ponceau 2 R.....	23	16	.....	.....
Methyl Alcohol.....	53	173	22	87	Ponceau 3 R.....	23	17	14	55
Methyl Blue.....	37	98	.....	.....	Ponceau 4 R B.....	28	48	13	51
Methyl Eosine.....	39	110	.....	.....	Ponceau 6 R B.....	29	51	14	56
Methyl Green.....	36	94	12	47	Potassium Chromate.....	55	178	20	80
Methyl Green OO.....	36	93	.....	.....	Potassium Permanganate.....	55	179	19	{ 74 75
Methyl Orange III.....	25	28	11	41	Praseodymium Ammonium Nitrate.....	56	180	26	100
Methyl Violet 6 B.....	36	92	17	66	Quinoline Blue.....	43	130	.....	.....
Mordant Yellow O.....	27	39	.....	.....	Quinoline Yellow O.....	43	131	11	44
Naphthalene Red.....	42	127	5	20	Quinoline Yellow, sol. in water..	43	131	11	44
$\beta$ -Naphtholdisulphonic Acid G....	21	2	1	{ 2 5	Red Violet 5 R S.....	37	96	16	62
Naphthol Green B.....	34	80	3	10	Resorcine (techn. pure).....	21	6	1	4
Naphthol Yellow.....	21	7	11	42	Resorcine Brown.....	27	41	10	38
Naphthol Yellow S.....	21	7	11	42	Rhodamine B.....	38	103	17	65
Naphthylamine Brown.....	25	33	.....	.....	Rosazurine B.....	32	70	.....	.....
Neodymium Ammonium Nitrate.....	53	174	25	{ 96 97 98	Rose Bengal.....	40	114	.....	.....
Neutral Red.....	41	121	.....	.....	Rosolane O.....	42	125	.....	.....
New Coccine.....	26	37	.....	.....	Safranine.....	42	123	.....	.....
New Coccine O.....	26	34	7	27	Sodium Bichromate.....	56	181	.....	.....
New Magenta.....	35	88	13	50	Sodium Nitroprussid.....	56	182	19	76
Nickel Nitrate.....	54	175	21	81	Soluble Prussian Blue.....	45	145	.....	.....
Nickel Sulphate.....	54	176	21	82	Thiogene Brown S.....	45	146	.....	.....
Night Blue.....	37	101	.....	.....	Thiogene Orange R.....	46	147	.....	.....
Nigrosine, soluble.....	42	126	.....	.....	Tropæoline O.....	24	25	.....	.....
$\lambda$ -Nitraniline. (Powder, "extra.")..	21	3	.....	.....	Tropæoline OO.....	25	29	.....	.....
<i>o</i> -Nitrobenzaldehyde.....	21	4	.....	.....	Tropæoline OOO No. 1.....	24	26	.....	.....
$\lambda$ -Nitrosodimethylaniline.....	21	5	1	3	Tropæoline OOO No. 2.....	25	27	.....	.....
Orange G.....	22	10	8	30	Uranine.....	38	107	4	{ 15 16
Orcein.....	45	144	.....	.....	Vesuvine.....	29	55	2	7
Phenosafarine.....	41	122	14	54	Victoria Blue 4 R.....	37	102	18	70
Phloxine.....	40	115	15	60	Water.....	56	183	22	87
					Wool Black.....	29	50	17	67

For convenience in identifying the stronger spark lines, fig. 99, pl. 25, is given.\* The numbers on this positive correspond to those preceding the wave-lengths below. The wave-lengths were derived from the two following sources:

“An Introduction to the Study of Spectrum Analysis,” by W. M. Watts. Longmans, Green & Co., 1904.

“Measurements of the Wave-lengths of Lines of High Refrangibility in the Spectra of Elementary Substances.” Hartley and Adeney. From the Philosophical Transactions of the Royal Society. Part I, 1884.

No.	W.-l.	Radia- tor.	No.	W.-l.	Radia- tor.	No.	W.-l.	Radia- tor.	No.	W.-l.	Radia- tor.
1.	2024.2	Zn.	27.	3133.3	Cd.	50.	{ 4070.0 } { 4072.4 } { 4076.1 }	Air.	70.	4649.2	Air.
2.	{ 2060.8 } { 2062.8 }	Zn.	28.	3250.5	Cd.	51.	4119.4	Air.	71.	4680.4	Zn.
3.	2099.0	Zn.	29.	3201.2	Cd.	52.	{ 4132.8 } { 4133.8 }	Air.	72.	4722.3	Zn.
4.	2138.3	Zn.	30.	3282.4	Zn.	53.	4145.9	Air.	73.	4800.1	Cd.
5.	2144.5	Cd.	31.	3302.7	Zn.	54.	{ 4151.9 } { 4153.6 }	Air.	74.	4810.7	Zn.
6.	2194.7	Cd.	32.	{ 3329.3 } { 3331.5 }	Air.	55.	{ 4228.5 } { 4236.7 }	Air.	75.	4912.3	Zn.
7.	2239.9	Cd.	33.	{ 3345.1 } { 3345.5 }	Zn.	56.	{ 4316.2 } { 4318.7 }	Air.	76.	4924.8	Zn.
8.	2265.1	Cd.	34.	3407.7	Cd.	57.	4349.5	Air.	77.	{ 5002.7 } { 5005.7 }	Air.
9.	2288.1	Cd.	35.	3436.9	Air.	58.	4397.9	Air.	78.	5045.7	Air.
10.	2306.7	Cd.	36.	{ 3466.3 } { 3467.8 }	Cd.	59.	4415.1	Air.	79.	5086.1	Cd.
11.	2313.0	Cd.	37.	3530.0	Cd.	60.	{ 4447.1 } { 4447.2 }	Air.	80.	5116.0	Zn.
12.	2321.2	Cd.	38.	{ 3613.0 } { 3613.0 }†	Cd.	61.	4530.1	Air.	81.	5146.2	Cd.
13.	2329.3	Cd.	39.	3682.6†		62.	4576.2	Cd. 92 †	82.	5338.6	Cd. —2
14.	2502.1	Zn.	40.	3712.2	Air.	63.	4601.6	Air.	83.	5354.4	Cd. —2
15.	2558.0	Zn.	41.	3726.6	Air.	64.	4607.3	Air.	84.	5379.3	Cd.
16.	2573.1	Cd.	42.	3749.8	Air.	65.	4614.0	Air.	85.	5497.4	Cd.
17.	{ 2710.1 } { 2712.6 }	Air. Zn.	43.	{ 3839.3 } { 3841.7 }	Air.	66.	4621.6	Air.	86.	5509.0	Zn. —2
18.	2748.7	Cd.	44.	3881.9	Air.	67.	4626.0	Cd. II2	87.	5541.8	Zn. 192
19.	2770.9	Zn.	45.	3919.2	Air.	68.	4630.7	Air.	88.	5602.0	Zn. 202
20.	2801.0	Zn.	46.	{ 3954.8 } { 3956.2 }	Air.	69.	{ 4641.9 } { 4643.4 }	Air.	89.	5761.8	Cd. 222
21.	2837.0	Cd.	47.	3972.5	Air.				90.	5961.6	Cd. 232
22.	2880.9	Cd.	48.	3995.1	Air.				91.	6014.0	Air. 242
23.	2980.8	Cd.	49.	4041.4	Air.				92.	6035.0	Zn. —2
24.	3007.0	Air.							93.	6071.8	Zn. 252
25.	3035.9	Zn.							94.	6144.4	Zn. 262
26.	{ 3072.2 } { 3076.0 }	Zn.							95.	6152.0	Zn. 262
									96.	6160.4	Cd. —2
									97.	6266.6	Cd. 272

The following table facilitates the finding of the numbers, names, etc., of all the substances which have an absorption spectrum more or less similar to that shown by a selected spectrogram. The third column gives the number of every substance referred in the text to the plate and figure of the preceding columns.

Plate.	Fig.	No.	Plate.	Fig.	No.
3	11	33, 63, 79, 116, 118, 135, 146.	12	46	83, 84, 85.
3	12	31, 147.	12	47	93.
3	13	39, 139.	13	51	49.
4	14	181.	13	52	37, 43, 137.
5	19	19, 61, 105, 125.	14	53	133.
5	20	126, 143, 144.	14	54	121, 123.
6	21	126, 138, 144.	14	55	16, 18, 20, 35, 36.
6	22	71, 72, 73, 75.	14	56	62.
6	23	38, 44.	15	58	110, 111.
7	25	70.	15	59	114.
7	26	59, 64, 65, 66, 67, 70, 140.	16	63	105.
8	31	26, 27.	17	66	90.
9	36	57, 58.	18	70	101.
10	37	25, 40, 53.	18	71	98.
10	39	42.	20	78	162.
10	40	9, 29.			

\* The negative was not a single exposure. To stand reproduction the extreme ultra-violet was "favored."  
 † "Doubtful Origin." ‡ The subscript 2 denotes the second order of spectrum.



32 .01 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20



FIG. 1.



FIG. 2.

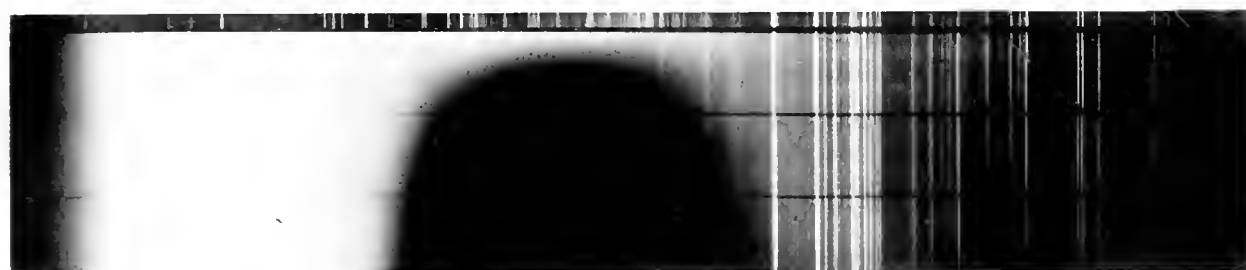


FIG. 3.



FIG. 4.

FIG. 5.

- FIG. 1. SEE NO. 1.  $\alpha$ -NAPHTHOL SULPHONIC ACID H.  
 FIG. 2. SEE NO. 2.  $\beta$ -NAPHTHOL SULPHONIC ACID G.  
 FIG. 3. SEE NO. 5. *p*-NITROSODIMETHYLANILINE.  
 FIG. 4. SEE NO. 6. RESORCIN.  
 FIG. 5. SEE NO. 2.





FIG. 6.



FIG. 7.

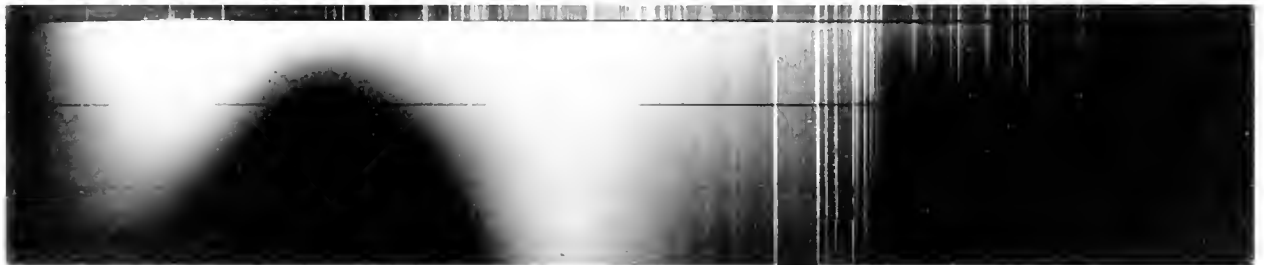


FIG. 8.

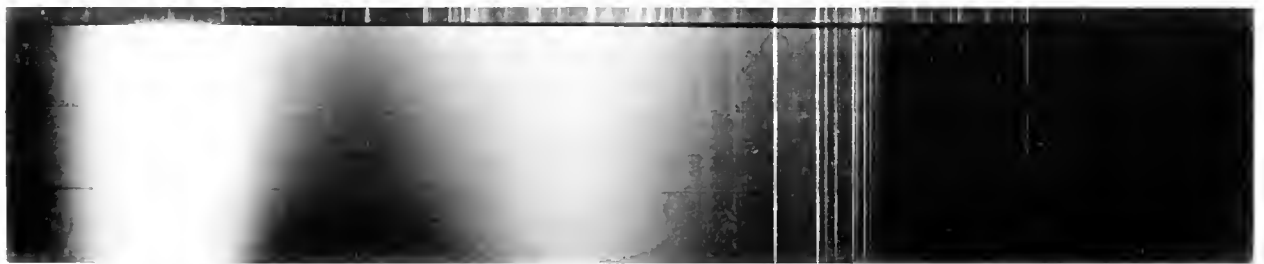


FIG. 9.

- FIG. 6. SEE NO. 11. FENNER
- FIG. 7. SEE NO. 12. CHRYS. DINE
- FIG. 8. SEE NO. 13. CHROMOTROPE B
- FIG. 9. SEE NO. 14. AZE. UCCINE 2 R.





82 .81 .80 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20

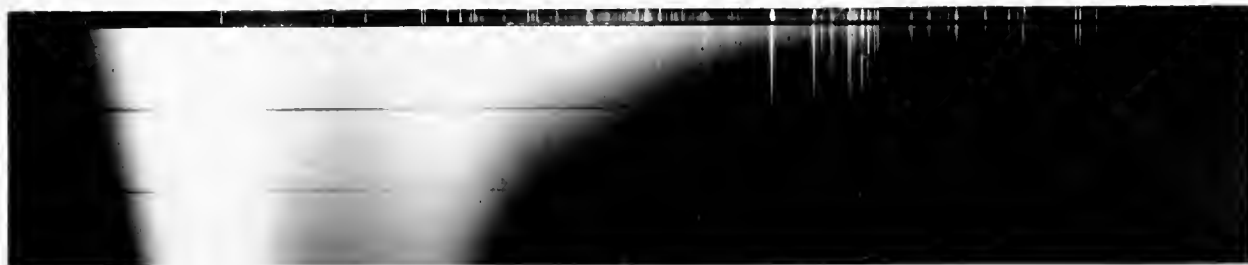


FIG. 10.

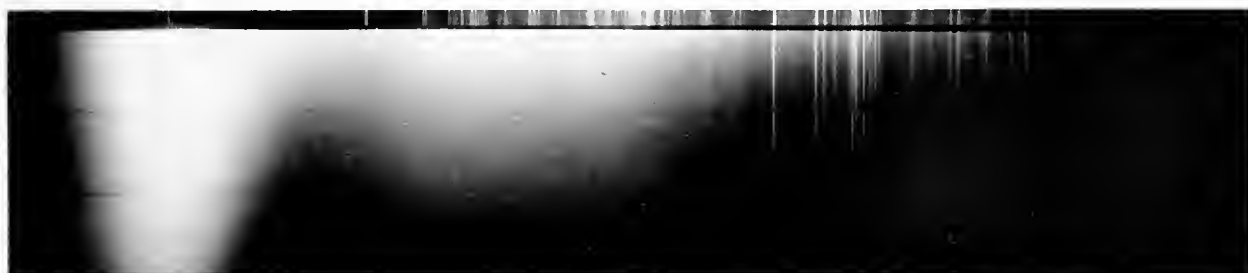


FIG. 11.

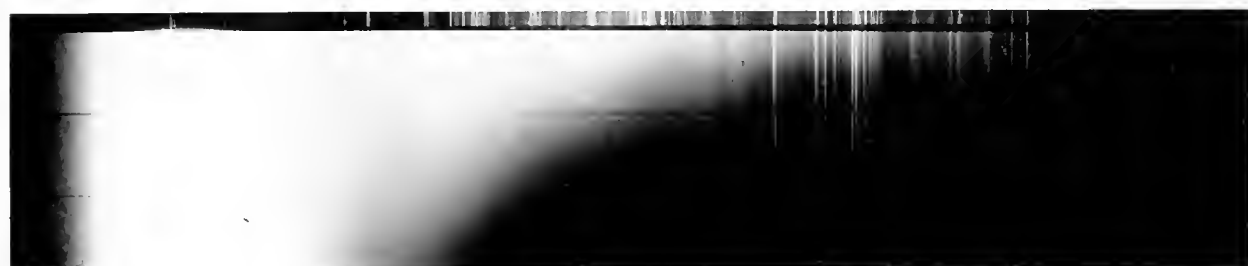


FIG. 12.

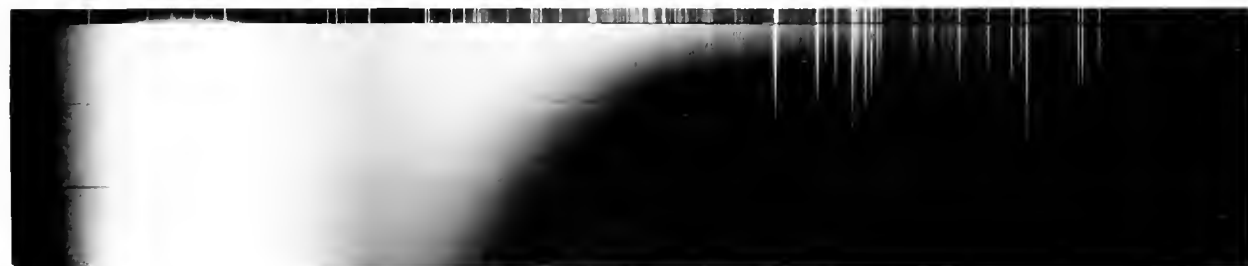


FIG. 13.

- FIG. 10. SEE NO. 80. NAPHTHOL GREEN B.
- FIG. 11. SEE NO. 47. CLOTH RED 3 G A.
- FIG. 12. SEE NO. 30. CURCUMEINE.
- FIG. 13. SEE NO. 129. COLUMBIA YELLOW.



02 .61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20



FIG. 14.

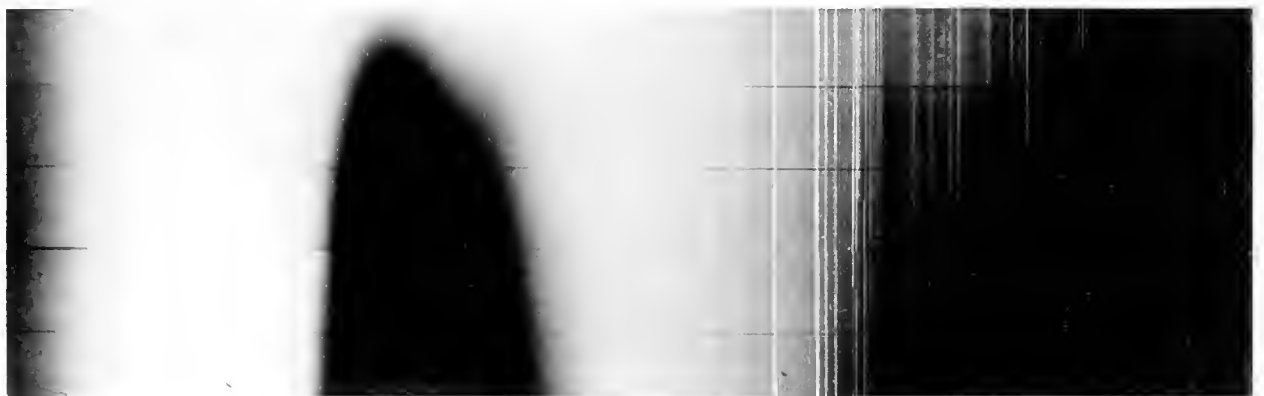


FIG. 15.



FIG. 16.

FIG. 14. SEE NO. 119. ALIZARINE RED S.

FIG. 15. SEE NO. 107. URANINE.

FIG. 16. SEE NO. 107. URANINE.



.02 .01 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20



FIG. 17.



FIG. 18.



FIG. 19.



FIG. 20.

- FIG. 17. SEE NO. 109. EDINE À L'ALCOOL
- FIG. 18. SEE NO. 113. CYANOSINE.
- FIG. 19. SEE NO. 106. ACID ROSAMINE A.
- FIG. 20. SEE NO. 127. NAPHTHALENE RED.



.02 .01 60 59 .58 .57 .56 .55 54 53 .52 .51 .50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21



FIG. 21.

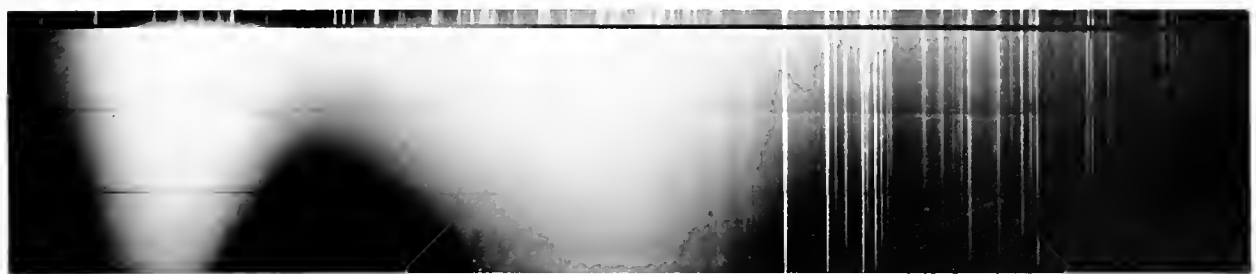


FIG. 22.



FIG. 23.



FIG. 24.

- FIG. 21. SEE NO. 46. CLOTH RED O.
- FIG. 22. SEE NO. 74. BENZOPURPURINE 10 B.
- FIG. 23. SEE NO. 60. CONGO CAR NTH G.
- FIG. 24. SEE NO. 134. ALIZARINE ORANGE.





62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22



FIG. 25.



FIG. 26.

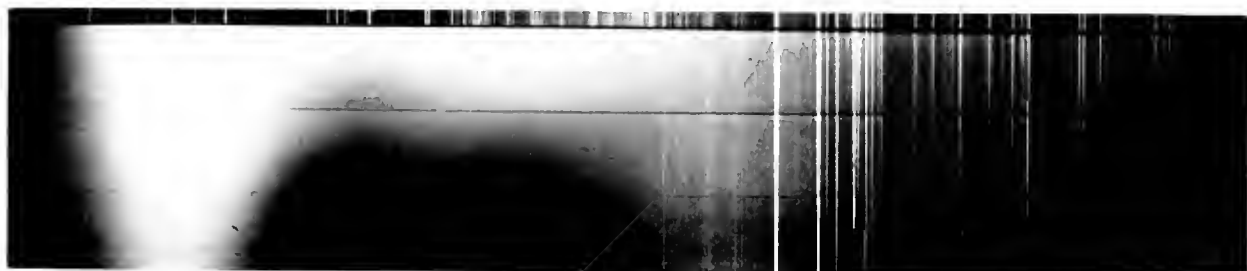


FIG. 27.



FIG. 28.

- FIG. 25. SEE NO. 45. CLOTH RED G.
- FIG. 26. SEE NO. 69. BRILLIANT PURPURINE R.
- FIG. 27. SEE NO. 34. FAST RED A.
- FIG. 28. SEE NO. 120. ALIZARINE BLUE S.



62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1



FIG. 29.



FIG. 30.



FIG. 31.

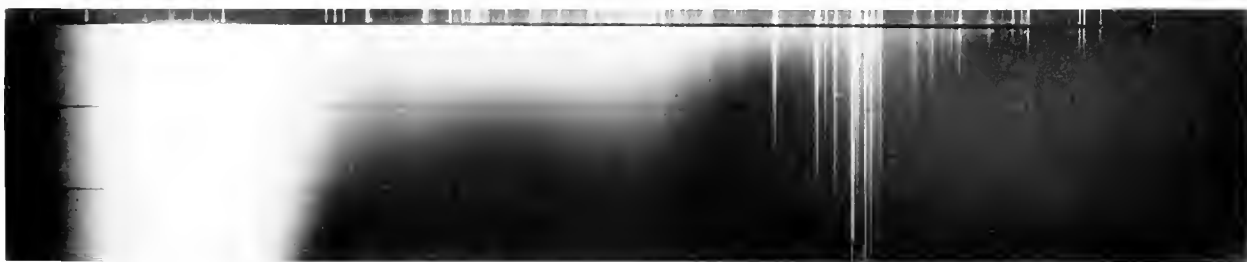


FIG. 32.

- FIG. 29. SEE NO. 23. EMIN RED.
- FIG. 30. SEE NO. 10. ORANGE G.
- FIG. 31. SEE NO. 15. BRILLIANT ORANGE G.
- FIG. 32. SEE NO. 117. PHOSPHINE.



1 .62 .61 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20

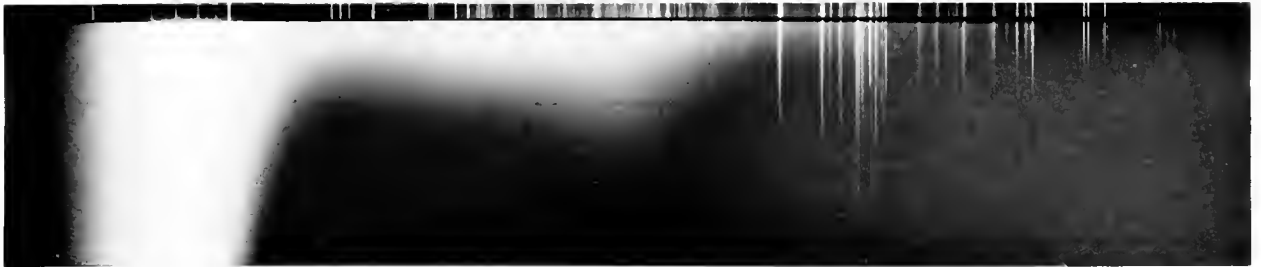


FIG. 33.



FIG. 34.

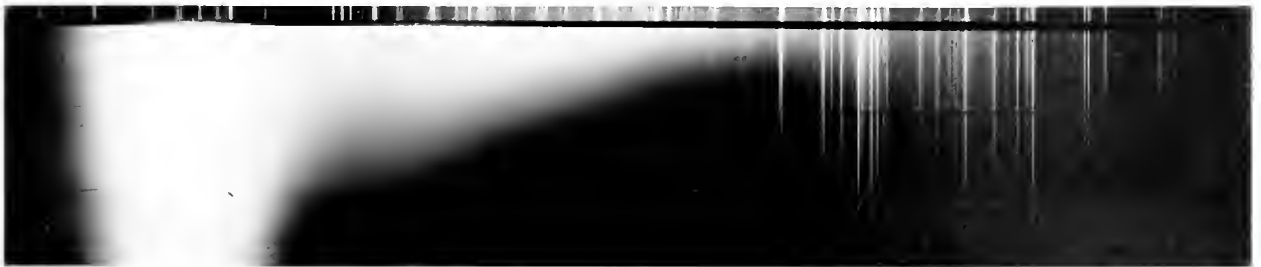


FIG. 35.

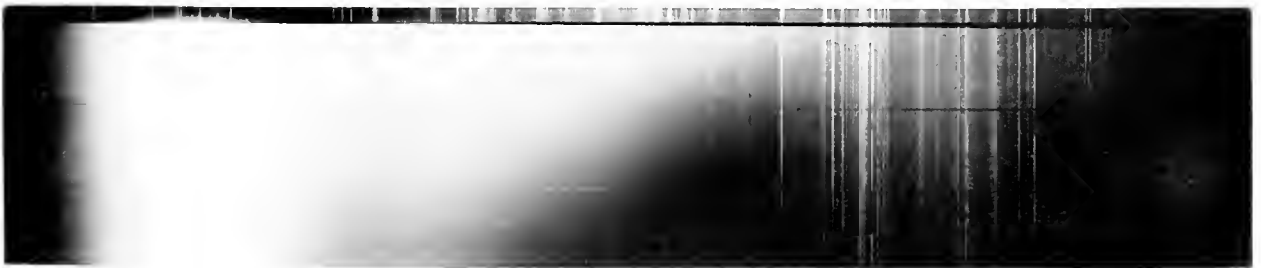


FIG. 36.

- FIG. 33. SEE NO. 56. CONGO ORANGE G.
- FIG. 34. SEE NO. 141. DIANIL ORANGE G.
- FIG. 35. SEE NO. 77. CONGO BROWN G.
- FIG. 36. SEE NO. 77. CONGO BROWN G.



.62 .61 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20

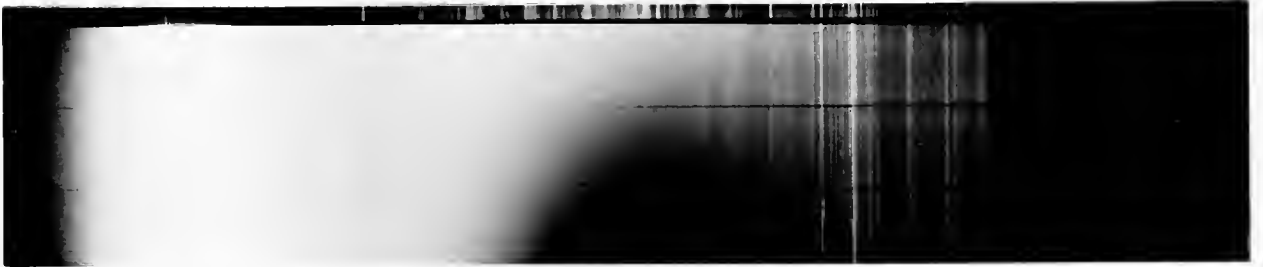


FIG. 37.



FIG. 38.



FIG. 39.

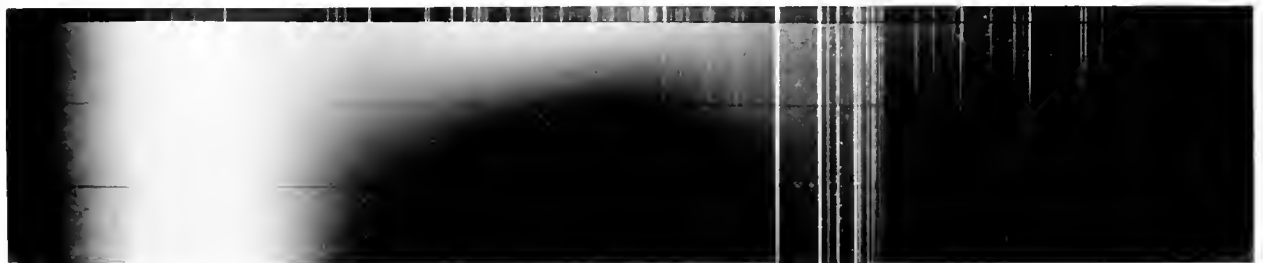


FIG. 40.

- FIG. 37. SEE NO. 31. ROSE BROWN.
- FIG. 38. SEE NO. 41. RESORCINE BROWN.
- FIG. 39. SEE NO. 8. AURANTIA.
- FIG. 40. SEE NO. 32. METANIL YELLOW.





.02 .01 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20

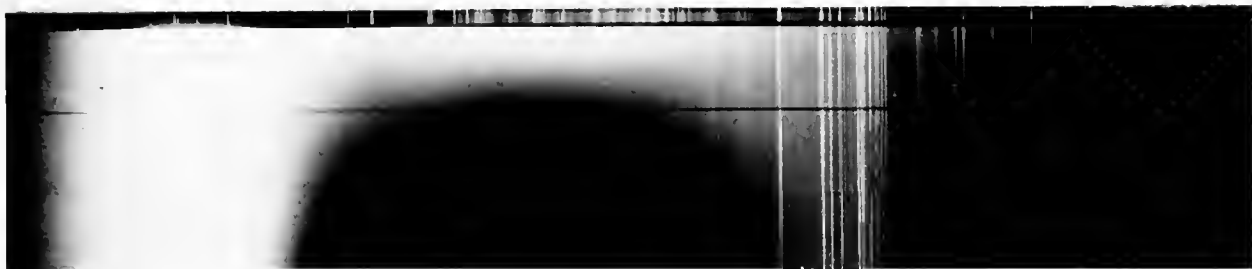


FIG. 41.

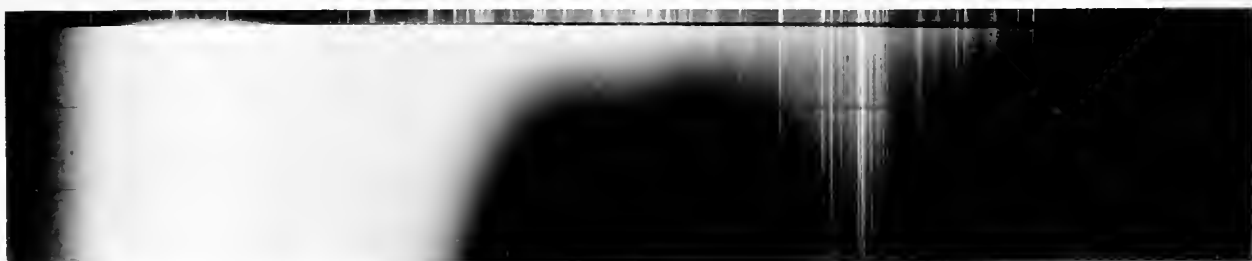


FIG. 42.

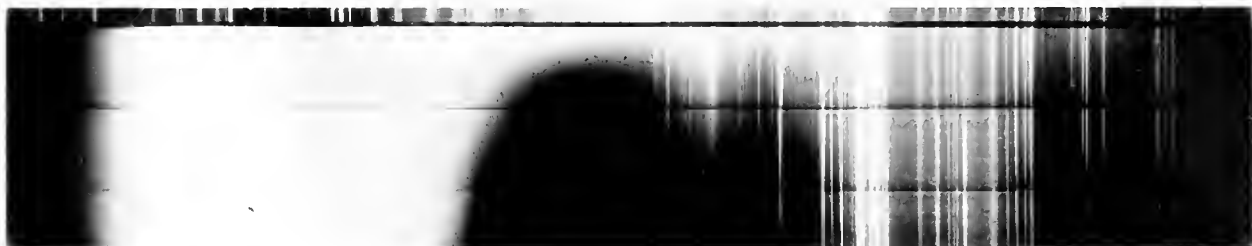


FIG. 43.



FIG. 44.

- FIG. 41. SEE NO. 28. METHYL ORANGE III
- FIG. 42. SEE NO. 7. NAPHTHOL YELLOW.
- FIG. 43. SEE NO. 82. AURAMINE O.
- FIG. 44. SEE NO. 131. QUINCLINE YELLOW G.



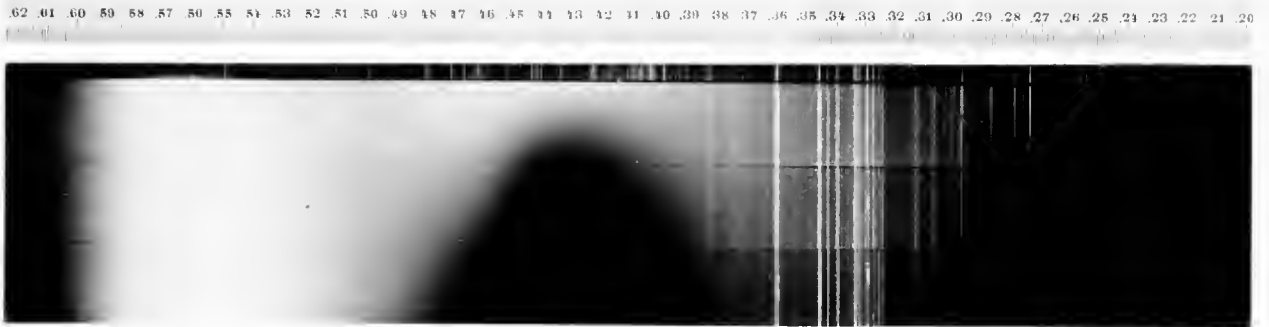


FIG. 45.



FIG. 46.

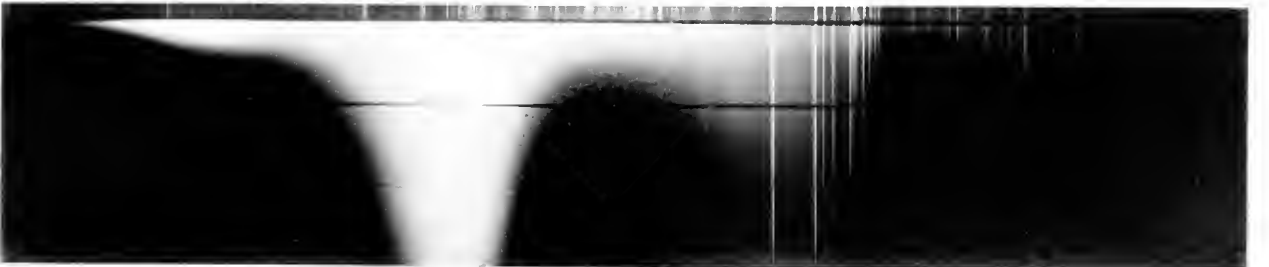


FIG. 47.



FIG. 48.

- FIG. 45. SEE NO. 136. 4,5-DIPHOSPHINE 4 G.
- FIG. 46. SEE NO. 85. ACID GREEN, CONC.
- FIG. 47. SEE NO. 84. METHYL GREEN.
- FIG. 48. SEE NO. 87. FUCHSINE.



.02 .01 .60 .80 .88 .87 .86 .85 .84 .83 .82 .81 .80 .79 .78 .77 .76 .75 .74 .73 .72 .71 .70 .69 .68 .67 .66 .65 .64 .63 .62 .61 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20



FIG. 49.



FIG. 50.



FIG. 51.



FIG. 52.

- FIG. 49. SEE NO. 100. CORALLINE RED.
- FIG. 50. SEE NO. 88. NEW MAGENTA.
- FIG. 51. SEE NO. 48. PONCEAU 4 R B.
- FIG. 52. SEE NO. 21. EOSAMINE B.



.02 .01 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20



FIG. 53.

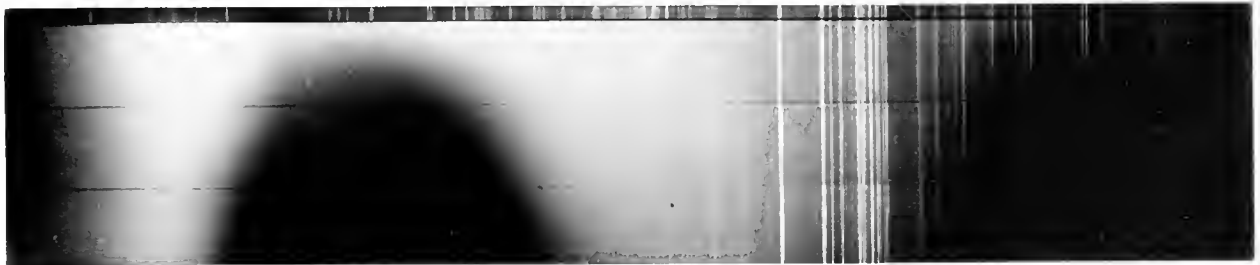


FIG. 54.

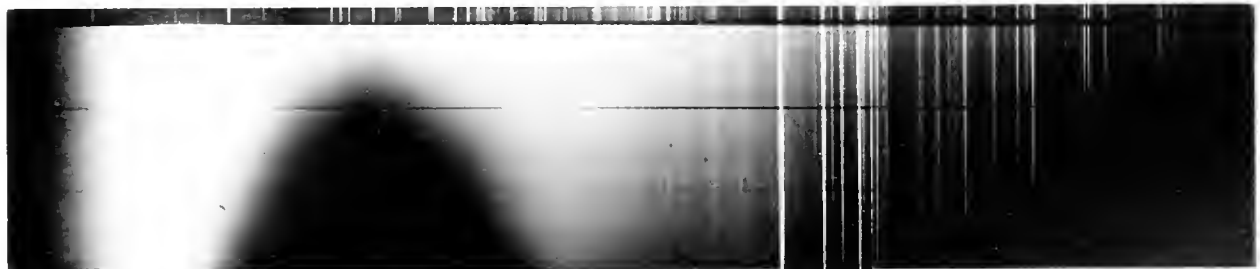


FIG. 55.



FIG. 56.

FIG. 53. 100% aperture. 100% aperture. 100% aperture.





82 .01 60 .59 58 .57 56 .55 54 .53 52 .51 .50 48 .47 46 .45 44 43 42 41 40 .39 38 .37 .36 .35 .34 .33 .32 31 .30 .29 28 27 .26 .25 24 23 22 .21 20



FIG. 57.

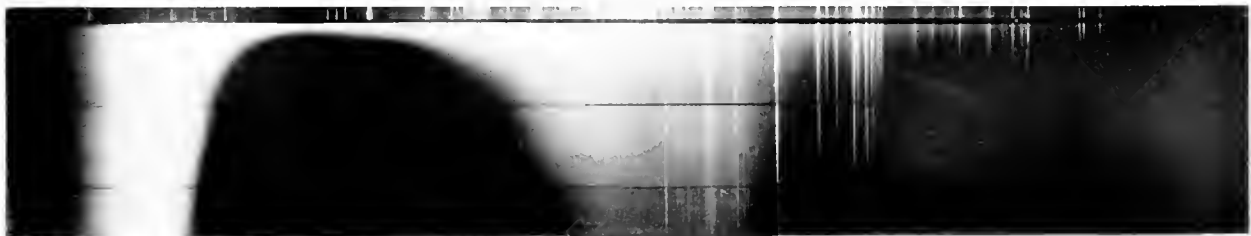


FIG. 58.



FIG. 59.



FIG. 60.

- FIG. 57. SEE NO. 12. ERIKALIN.
- FIG. 58. SEE NO. 108. EDSNE, H<sub>2</sub>O, WITH H.
- FIG. 59. SEE NO. 111. ERVTHRONE.
- FIG. 60. SEE NO. 113. PHOTONE.



.62 .61 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20



FIG. 61.

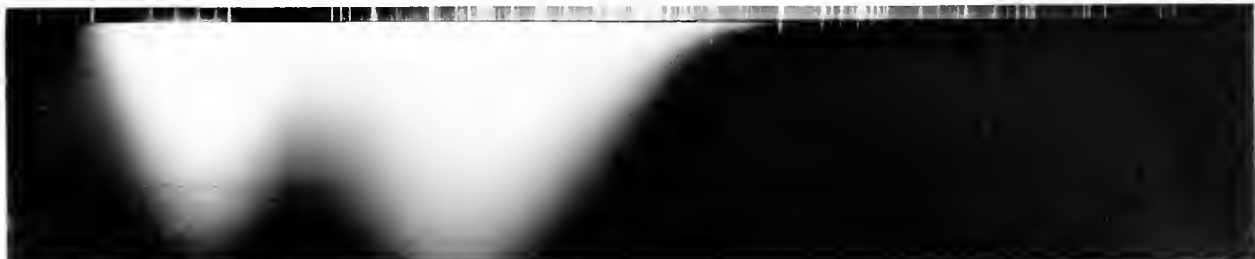


FIG. 62.

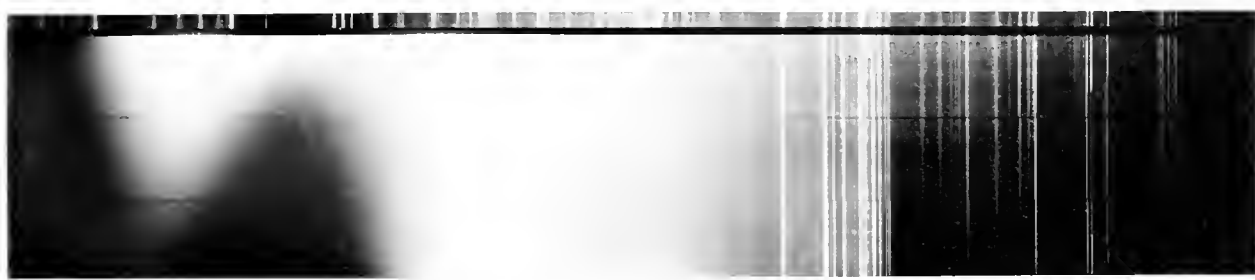


FIG. 63.



FIG. 64.

- FIG. 61. SEE NO. 68. DIMETHYL ETHER
- FIG. 62. SEE NO. 96. PENTANOL
- FIG. 63. SEE NO. 104. FORMALDEHYDE
- FIG. 64. SEE NO. 91. ETHYL ALCOHOL



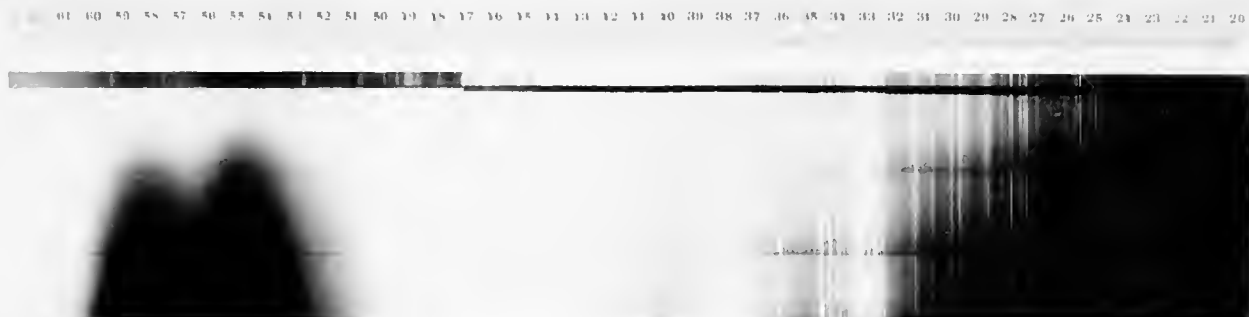


FIG. 65.



FIG. 66.



FIG. 67.



FIG. 68.

- FIG. 65. SEE NO. 103. RHODAMINE B
- FIG. 66. SEE NO. 92. METHYL VIOLET 6B.
- FIG. 67. SEE NO. 50. WOOL BLACK.
- FIG. 68. SEE NO. 124. HELIOTROPE 2B.



2 .61 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20



FIG. 69.



FIG. 70.

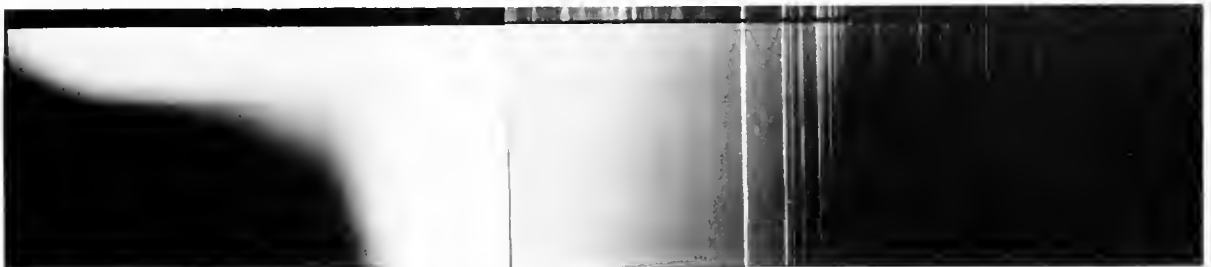


FIG. 71.

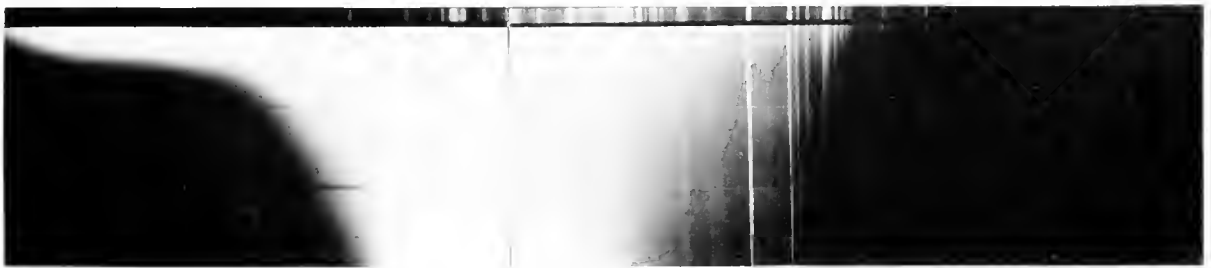


FIG. 72.

- FIG. 69. SEE NO. 89. DAHLIA.
- FIG. 70. SEE NO. 102. VICTORIA BLUE 4R
- FIG. 71. SEE NO. 99. CHINA BLUE
- FIG. 72. SEE NO. 97. ALKALI BLUE 6B





.02 .01 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20



FIG. 73.



FIG. 74.



FIG. 75.

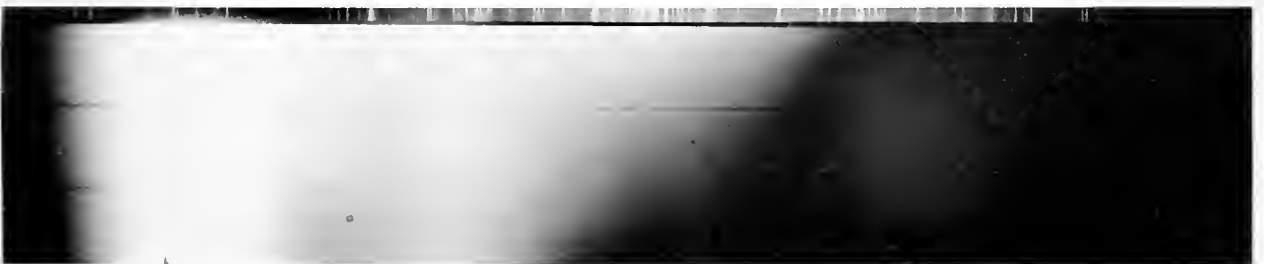


FIG. 76.

- FIG. 73. SEE NO. 144. AER. D. W. L.
- FIG. 74. SEE NO. 179. POTASSIUM PERMANGANATE.
- FIG. 75. SEE NO. 170. POTASSIUM PERMANGANATE.
- FIG. 76. SEE NO. 182. SODIUM NITROPRUSSID.



.62 .61 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 20

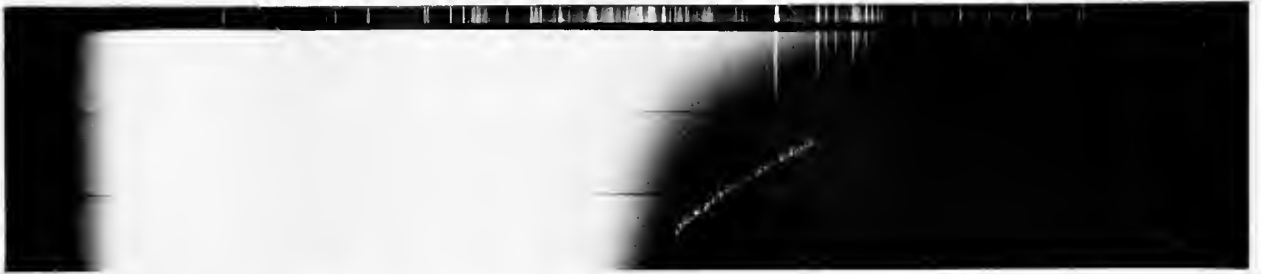


FIG. 77.



FIG. 78.



FIG. 79.

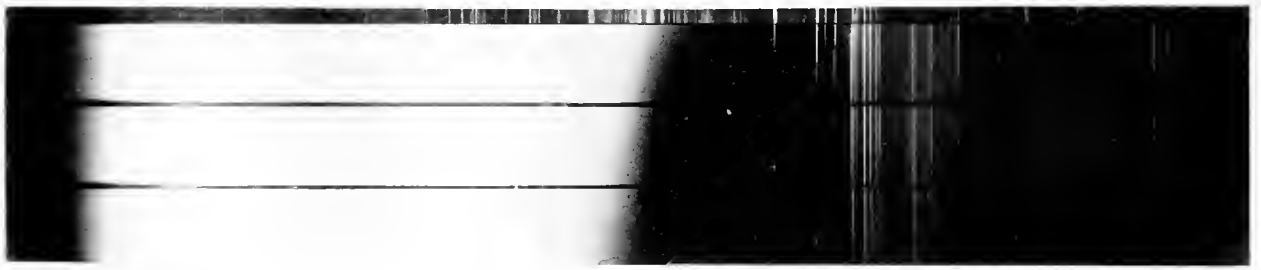


FIG. 80.

- FIG. 77. SEE NO. 153. COPPER CHLORIDE.
- FIG. 78. SEE NO. 156. COBALT CHLORIDE.
- FIG. 79. SEE NO. 155. CHROMIUM CHLORIDE.
- FIG. 80. SEE NO. 178. POTASSIUM CHROMATE.



1 .01 .60 .50 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20

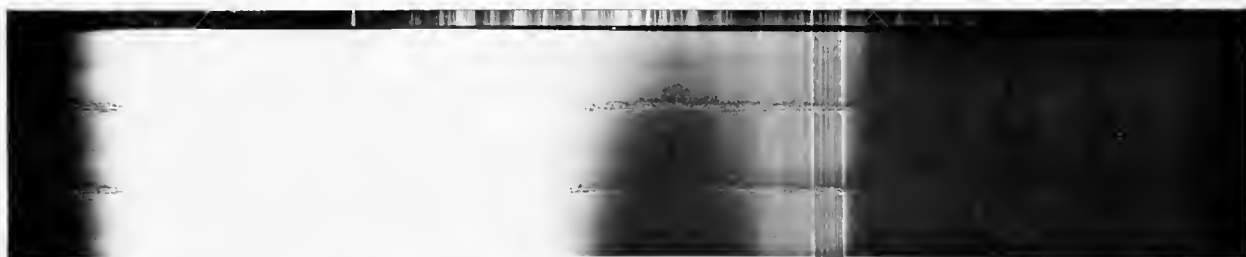


FIG. 81.



FIG. 82.



FIG. 83.

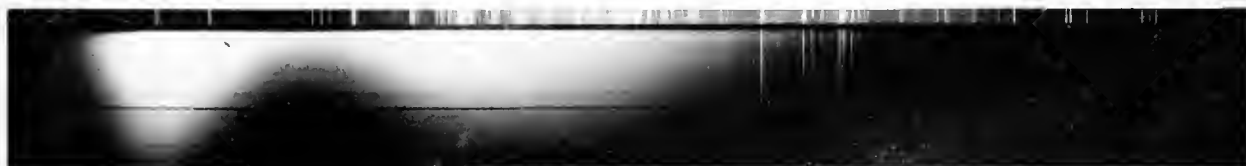


FIG. 84.

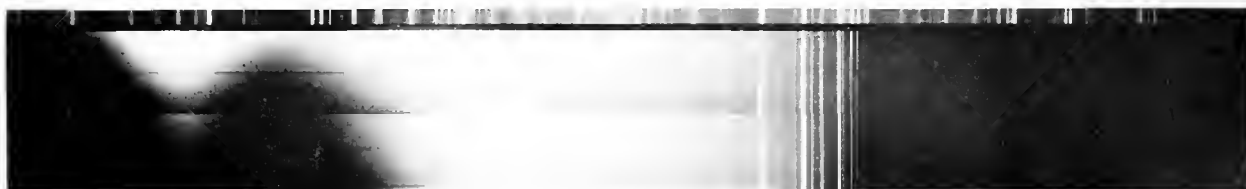


FIG. 85.

- FIG. 81. SEE NO. 175. NICKEL NITRATE.
- FIG. 82. SEE NO. 176. NICKEL SULPHATE.
- FIG. 83. SEE NO. 172. LITMUS, BLUE.
- FIG. 84. SEE NO. 172. LITMUS, RED.
- FIG. 85. SEE NO. 161. COBALT GLASS.



3 .92 .61 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21



FIG. 86.



FIG. 87.



FIG. 88.



- FIG. 86. SEE NO. 1.
- FIG. 87. SEE NO. 4.
- FIG. 88. SEE NO. 11.
- FIG. 89. SEE NO. 14.









.62 .01 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20



FIG. 93.

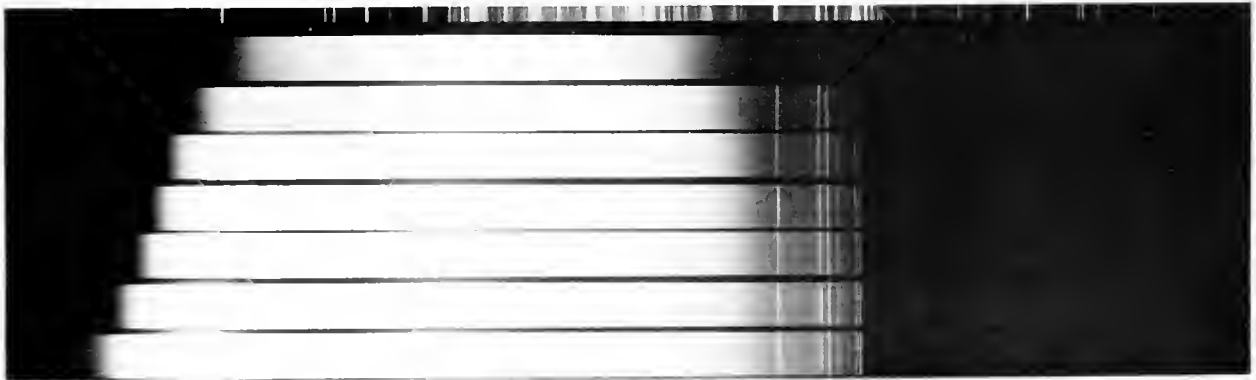


FIG. 94



FIG. 95

FIG. 93. SEE NO. 160. COPPER CHLORIDE IN ACETONE.

FIG. 94. SEE NO. 158. COBALT CHLORIDE IN ACETONE.

FIG. 95. SEE NO. 157. CHLORIDES OF ALUMINIUM AND COBALT.



12 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20



FIG. 96.

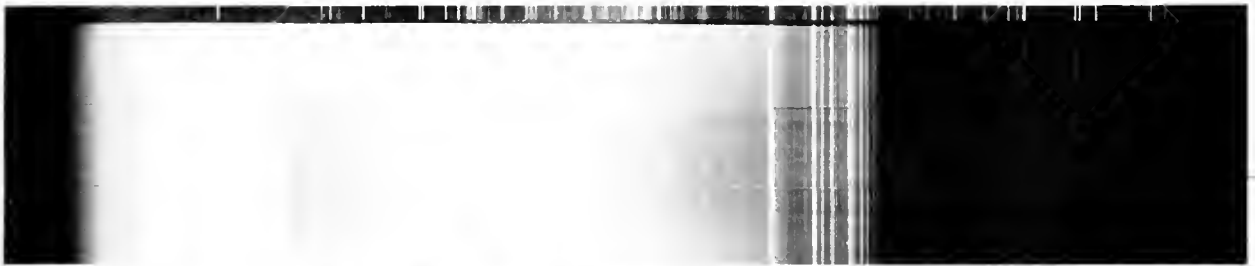


FIG. 97.



FIG. 98.

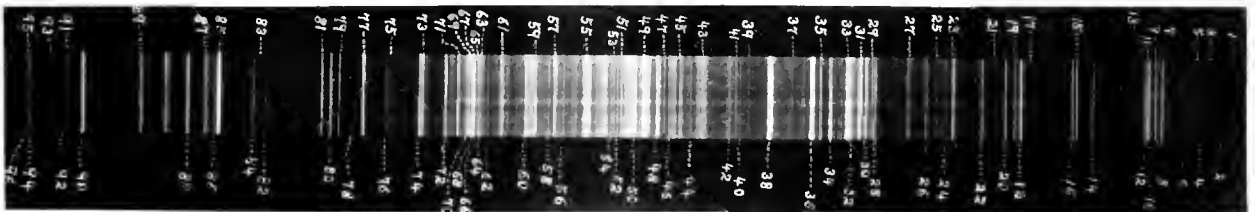


FIG. 99.

FIG. 96. SEE NO. 174. NEODYMIUM AMMONIUM NITRATE.  
FIG. 97. SEE NO. 174. NEODYMIUM AMMONIUM NITRATE.  
FIG. 98. SEE NO. 174. NEODYMIUM AMMONIUM NITRATE.  
FIG. 99. SEE PAGE 169.



.62 .61 .60 .59 .58 .57 .56 .55 .54 .53 .52 .51 .50 .49 .48 .47 .46 .45 .44 .43 .42 .41 .40 .39 .38 .37 .36 .35 .34 .33 .32 .31 .30 .29 .28 .27 .26 .25 .24 .23 .22 .21 .20

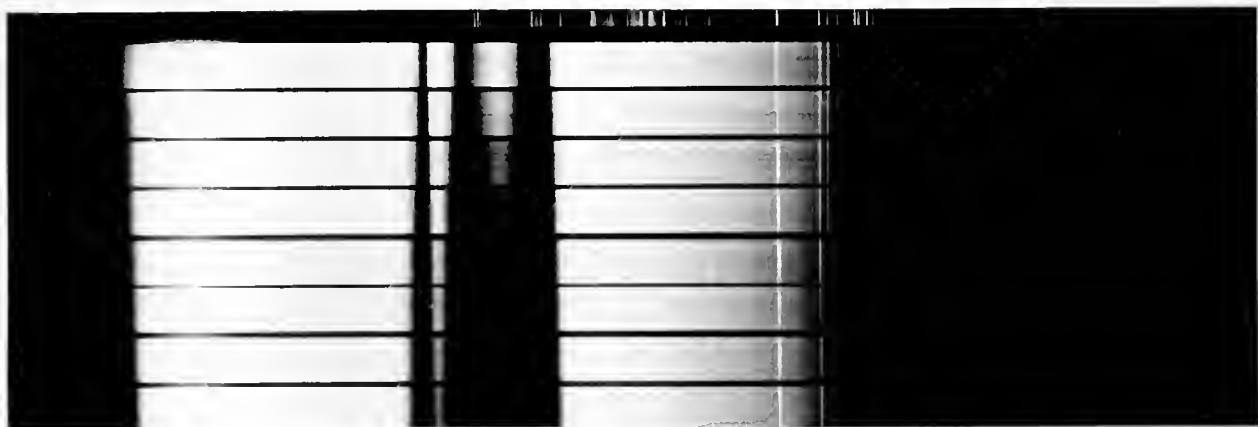


FIG. 100.



FIG. 101.



FIG. 102.

FIG. 100. SEE NO. 180. PRASEODYMIUM AMMONIUM NITRATE.

FIG. 101. SEE NO. 169. ERBIUM CHLORIDE.

FIG. 102. SEE PAGES 5 AND 20

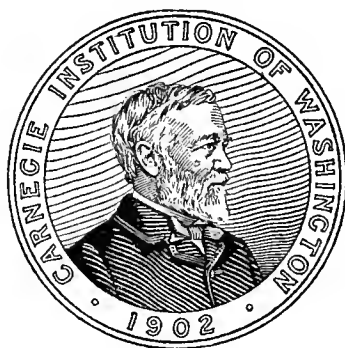




# ATLAS OF ABSORPTION SPECTRA

BY

H. S. UHLER and R. W. WOOD



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May, 1907











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