

The Spectrodensograph, a Registering Apparatus for Determining the Absorption Curves of Dyestuffs

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The chemical qualities of coloured substances have been carefully investigated, but our knowledge of their optical constants lags far behind, although it is just these which settle the practical use of the colouring matters. The reason for this remarkable state of affairs is that there has not existed until now a simple means of determining in figures the composition of the light reflected by a coloured body or transmitted through it. Of course the spectrum informs us most perfectly upon this head, but it must be admitted that the absorption spectrum does not by itself define the appearance of a colour, that is to say, its shade, although it settles this. On this account a number of attempts have been made to express the appearance of a colour in numbers by means of some colour system, but in spite of this the absorption spectrum is still the most important characteristic of every coloured substance from the optical point of view.

Absorption spectra are at present generally found by the aid of a spectrophotometer or spectrographically, but the use of these apparatus is very tiresome. When working with the spectrophotometer the extinction coefficient must be determined, that is to say, the weakening of the light in each spectral division, and the curve plotted. The photometrical part of the work is tedious and not exactly pleasant. Light which has passed

through a colouring matter and has been split up spectrally is not very strong, particularly at the blue end of the spectrum, even when powerful sources of light are used. The work must consequently be done in a darkened room and is inclined to strain the eyes, because a lamp must be switched on each time a photometric reading is made which always destroys the heightened sensitiveness of the eye produced in a short time by the darkness. The calculation and plotting of the curve is a fertile source of error. When measuring in deep red, blue, and violet, the yellow and yellowish green part of the spectrum causes most disturbance by reflexions within the photometer unless care has been taken beforehand by the use of a monochromator that only that part of the spectrum which is actually being measured at the moment shall reach the photometer itself. But the use of the monochromator brings with it the further great disadvantage that not merely the photometer, but also the monochromator must be adjusted at every new measurement to the new spectral field.

This is probably the reason why an atlas of the absorption curves of the organic dyes does not exist even at the present day.

The spectrodensograph is intended to afford the possibility of determining in the simplest way the absorption curves of colouring matters, that is to say, of coloured solu-

tions and of colourations. This instrument is really the application of the densograph to the technics of spectral analysis and was completely constructed already in 1914 by the author in collaboration with Mr. André Callier, of Ghent. Owing to the war publication has been delayed until now.

The apparatus is shown in Figure 1 and consists, as can be seen from Figure 2, of two separate parts which are so connected that they can be simultaneously adjusted. The first part (I) is a monochromator comprising the source of light 1 (Wolfram point arc lamp), the collimator lens k_1 , the prism p_1 , and the objective o_1 . The latter is a double

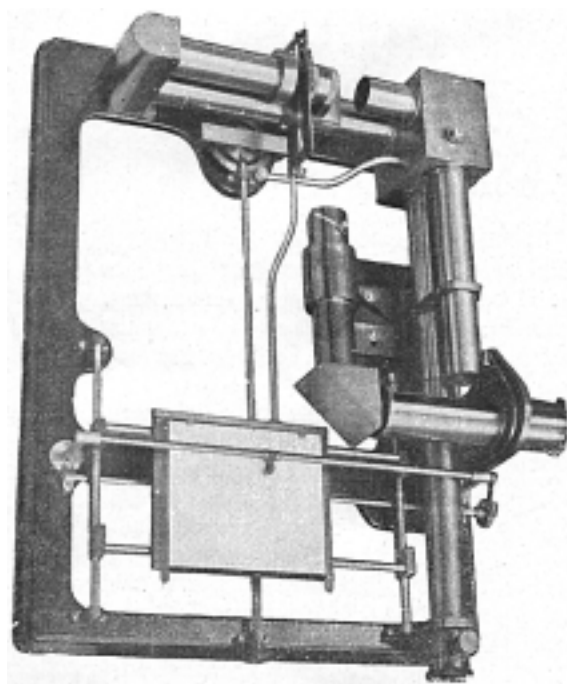


Fig. 1

lens such as is generally used to illuminate spectrometers (Figure 3), so that two small spectra of the source of light, which serves in this case as a slit, are formed in the focal plane of the objective o_1 . The focal plane of the monochromator objective, in which the two superimposed spectra are contained, coincides with the fixed slit s of the actual spectrophotometer. The spectrophotometer part consists of the slit s , the collimator k_2 , the prism p_2 , the objective o_2 , and the ocular slit a . A sharp image of the slit s and the two spectra figured upon it by means of the monochromator is formed in the ocular slit. The images of these spectra are now super-

imposed upon one another by the aid of the twin prism z (Figure 3) at the objective o_2 , so that only a single image is seen in the ocular slit. By the aid of this construction, which has often been applied in photometric instruments, the separate rays which are produced by the double lens o_1 , are brought together again so that the observer upon looking into the ocular slit sees the upper part of the twin prism z in the light which comes from the lower part of the double lens o_1 , while the lower part of the twin prism z is illuminated by the light coming from the upper part of the double lens o_1 . If a coloured substance is now placed in the upper ray of light and an arrangement for weakening the light (in this case a grey wedge) is placed in the lower ray, then both parts of the twin prism z can be uniformly illuminated by weakening the lower ray.

The prisms p_1 and p_2 are each connected with a lever h_1 and h_2 by the action of which the monochromator and the spectrophotometer can be adjusted to the spectral field chosen.

The construction of the apparatus is greatly simplified by its division into two parts at the line A-B which are closed together like an open book. Two reflecting prisms of 90° are fixed at the point of intersection which deflect the light ray twice. By this means the axis of the prism p_1 lies exactly upon the axis of the prism p_2 and the levers h_1 and h_2 coincide. Thus the monochromator prism is automatically coupled with the photometer prism. The movement of the now single lever causes such a change of position of the two small spectra at the slit s that the colour placed in the monochromator continually appears in the ocular slit a of the photometer. This device therefore entirely does away with the wearisome fresh adjustment of the monochromator to harmonize with the photometer.

The device for registering is comparatively simple. The movement of the lever h , which serves to adjust the spectrum field in the photometer, follows the curved path v (Figure 4). The curve is set in motion by toothed gearing t , the axle of which moves the registering table from left to right by means of rack and pinion drive. Thus when the spectral field is shifted by the milled screw n immediately before the observer, the paper placed upon the table moves in the direction of the abscissa with the speed accurately determined by the rack and pinion motion

and the form of the curve. If the table is divided from left to right into wave lengths, the prism can be adjusted according to every position of the table. It is even possible to convert the form of the spectrum which is very awkward for practical purposes and depends upon the quality of the glass used, into the uniform division of the bent spectrum.

The reduction in the strength of the one light ray, which is necessary to produce uni-

on and the colouring matter is laid in the upper part of the light ray of the monochromator at *m* (Figure 1). Coloured solutions are placed in a small tray *m*, well known in other connections, the lower part of which is filled with a piece of glass about 20 millimetres long (the so-called Schulz body). The observer keeps his left hand on the screw n_1 and his right hand on the screw n_2 , and by means of n_1 moves the table to the right as far as it can go, whereby the deepest red

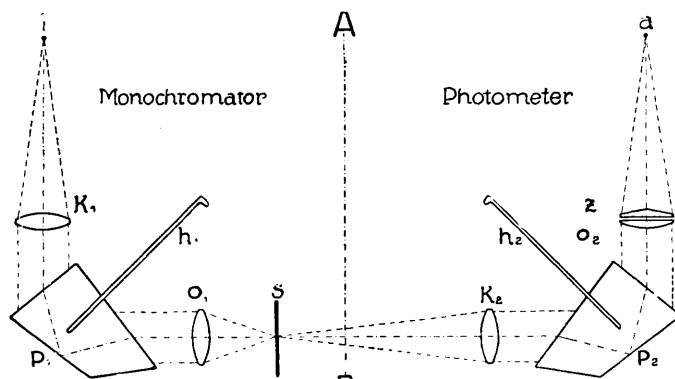


Fig. 2. Path of the rays seen from above.

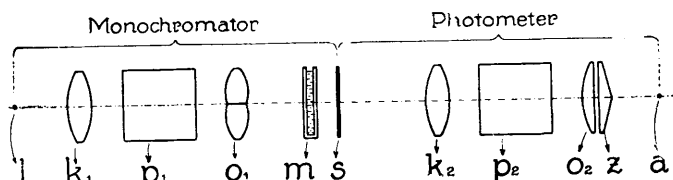


Fig. 3. Path of the rays from the side (opened bookways).

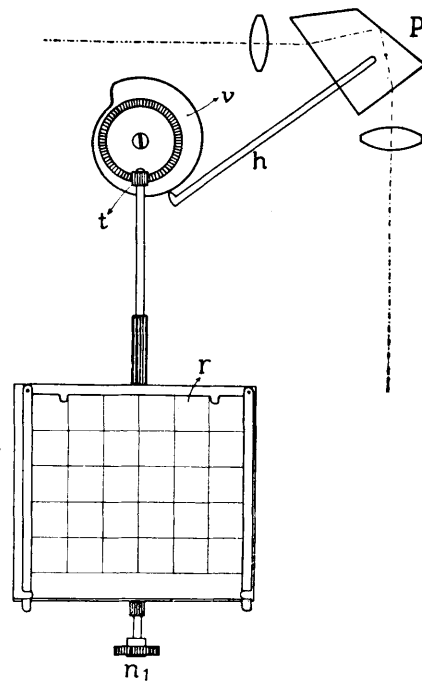


Fig. 4. Recording the wave lengths.

formity and in order to determine the absorption in the spectral field in question, is carried out, as mentioned above, by means of a grey wedge (cf. Figure 5). This motion is actuated by means of a rack and pinion set in motion by a milled screw n_2 . The rack is firmly connected with the registering table *r*, so that simultaneously with the movement of the wedge *d* the registering table and the graph sheet attached to it move downwards, i. e. in the direction of the ordinate.

A small pin *f* with a fine point is situated under the table (Figure 6) and can be lowered onto the paper by means of the lever *b* at the side of the apparatus. This causes a tiny prick in the paper which then forms the abscissa curve.

Measurements are carried out in the simplest way conceivable. The light is switched

appears automatically in the field of view. Uniformity in the field of view is adjusted by the screw n_2 . The lever *h* immediately above the screw n_2 is actuated without removing the right hand from the screw. The graph paper it thus automatically pricked at the ordinate corresponding to the red rays in the abscissa corresponding to the coefficient of extinction in question. Thereupon the screw n_1 is turned, keeping the field all the while in view, until a difference can be observed in the field of view, that is to say, until the coefficient of extinction has noticeably changed. Then the screw n_2 is moved a little till uniformity is secured again, a second prick is made, and so on (see Figure 7). This method of measurement and notation has at the same time the advantage of not having to make an unnecessarily large number of mea-

surements at places where the abscissa curve flattens out.

The apparatus is as exact as the curves found in publications generally are, which is to say that it is accurate enough for all prac-

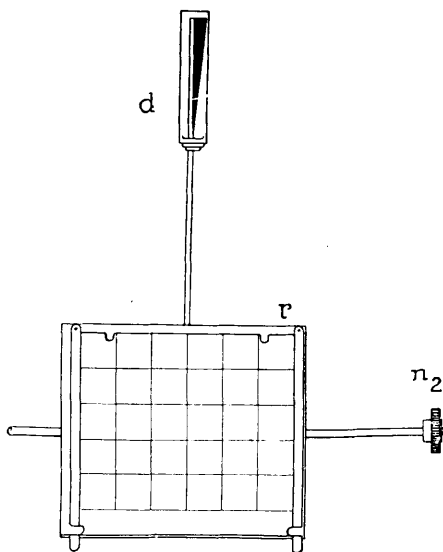


Fig. 5.

Recording the coefficient of absorption.

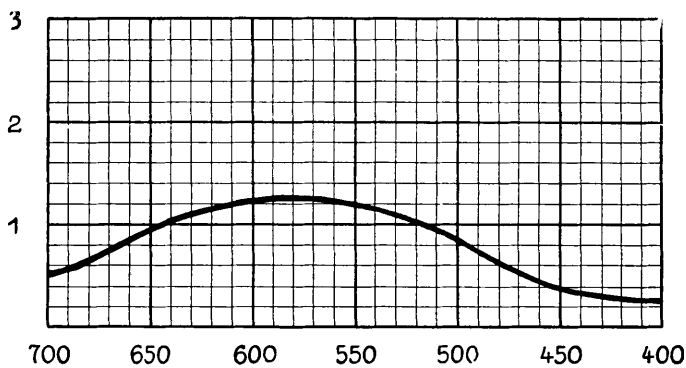


Fig. 7.

tical purposes. The wave lengths harmonize exactly to about from 2—3 $\mu\mu$. The extinction coefficients are accurate to about 0.05 in logarithmic units. The thickness of the curve shown in Figure 7 meets the accuracy required by the instrument.

A very important field of observation, but one which has hitherto been neglected, is the

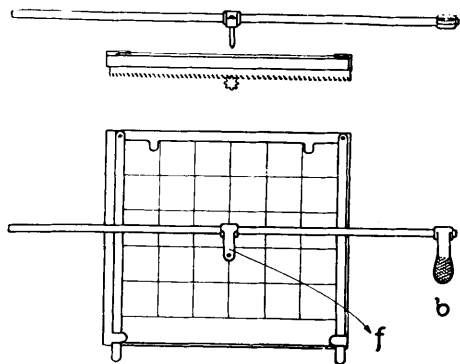


Fig. 6. Record pin.

determination of the absorption curves of colourations on paper, fabric, and so on, for which purpose the colouring matters are chiefly used in practice. Apparatus are hardly

even known which can carry out such simple measurements, but the spectrodensograph permits of this being done very easily. Part of the light from the arc lamp is thrown by means of the lens *e* and the mirror *g* (Figure 8) upon the coloured body *u* to be examined which has been fastened at an angle of 45° to the axis of the apparatus. The spot of light must then occupy the position of the upper spectrum of the monochromator. The underpart of the photometrical field of view is thereby illuminated by the light from the coloured body to be examined, while the up-

per part still receives light directly from the arc lamp. By inducing equilibrium in the field of view, as described above, the curve is automatically registered upon the graph

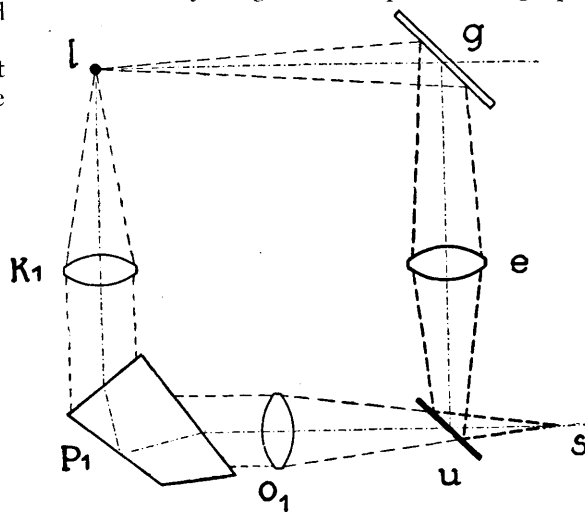


Fig. 8. Illumination from above.

paper. Of course the information given by this curve no longer corresponds to the normal extinction coefficient. In order to reach zero, a piece of white paper must be

inserted instead of the coloured body before or after the tests and the zero line settled by inducing equilibrium in the photometric field of view.

To sum up, the spectrodensograph possesses the following properties:

1. By its means there can be determined the absorption curves of liquid and solid transparent coloured bodies of a thickness up to 30 millimetres, as well as of solid non-transparent coloured bodies such as paper, fabric, etc.

2. Measurements are made in the dark, so that the eye is not disturbed by reading off.

3. The curve is produced automatically during the measurements and does not need to be calculated and plotted.

4. With the aid of the spectrodensograph a curve can be determined in from two to three minutes as against the hours hitherto found necessary.

5. Reflexions such as occur in the ordinary spectrophotometers, which make measurements in the dark parts of the spectrum illusory, are here eliminated by the automatic adjustment of the monochromator.

6. The absorption curves can be determined by totally unskilled personnel.