

ON SOME OPTICAL PROPERTIES OF ASPHALT.

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WHEN a thin layer of asphalt varnish is spread upon glass and allowed to dry and some luminous source, such as the filament of an incandescent lamp, is observed through the film, it is found that a considerable amount of red light is transmitted, the unusual purity of which is readily ascertained by means of a spectroscope. The suddenness with which the rays beyond the red are cut off indicates the existence of a well-defined absorption band with a very steep gradient on the side toward the greater wavelengths; and one would expect to find a considerable degree of perviousness in the infra-red and anomalous dispersion in the region where the change from transparency to opacity occurs.

It is the purpose of this paper to describe some studies of this interesting substance concerning the optical properties of which nothing appears to have been recorded.

SPECTRO-PHOTOMETRIC OBSERVATIONS.

For the purpose of determining the transmitting power of asphalt in the visible spectrum, films of the requisite thickness were obtained by dipping a piece of thin plate glass into asphaltum varnish and allowing the coating to dry; after which one side of the glass was carefully cleaned. The film thus obtained covered about one half of one face of the glass plate. The instrument employed in the determination of the transmitting power of the film was a one-prism spectroscope provided with a Vierordt slit. The spectroscope was securely clamped above the table with the circle *C* in a vertical plane, the collimator tube horizontal, the slit horizontal and the observing telescope moving in a vertical arc. Light for the comparison spectrum was introduced through the right hand half of the slit by means of a total reflection prism *P* (Fig. 1). The source of light was an acetylene flame (*A*₁) in front of which, in order to reduce the intensity, two thicknesses of ground glass (*G*) were interposed.

Light from a similar acetylene flame (A_2) which was mounted in the line of the collimator, entered the left half of the slit directly. The glass plate (f), with the asphalt film, was interposed in the path of this ray near the slit. By giving the plate a lateral movement of about two centimeters, the ray could be caused to pass alternately through the glass and asphalt and through the glass alone. A comparison of the absorption spectra thus obtained with the spectrum from (A_1) furnished data for computing the transmitting power of the asphalt film.

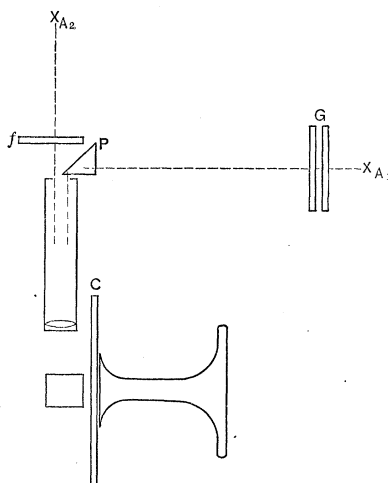


Fig. 1.

Measurements were made in five regions of the spectrum lying between $.73 \mu$ and $.589 \mu$. The transmission of light of wave-lengths shorter than the latter was too faint to be measured. The thickness of this film, determined by measuring with a micrometer gauge the thickness of the glass and of the glass and asphalt together was found to be 0.003 cm . Table I. gives the percentage of light transmitted by the asphalt and the extinction coefficient of this substance for the regions of the spectrum in which measurements were possible.

The extinction coefficient was computed in the form used by Knut Ångström¹ with whose results with films of lampblack it was desired to compare the present measurements.

The equation has the well-known form

$$I_e = I_0 e^{-kl},$$

where I_0 is the intensity of the incident ray, I_e that of the ray transmitted by a film of thickness l and k is the extinction coefficient.

The transmission curve for the visible spectrum is shown in Fig. 2. It will be seen from these data that a film of this thickness becomes almost completely opaque in the yellow, the transmission in the

¹ Ångström, Wiedemann's Annalen, 36, p. 715 (1889).

TABLE I.

Transmission in the visible spectrum of a layer of asphalt .003 cm. in thickness.

Wave-lengths.	$\frac{I_0}{I_o}$	Extinction Coefficients ² (k).
0.730 μ	0.0233	1256
0.680 μ	0.0088	1558
0.656 μ	0.0044	1813
0.617 μ	0.00085	2362
0.589 μ	0.00038	2631

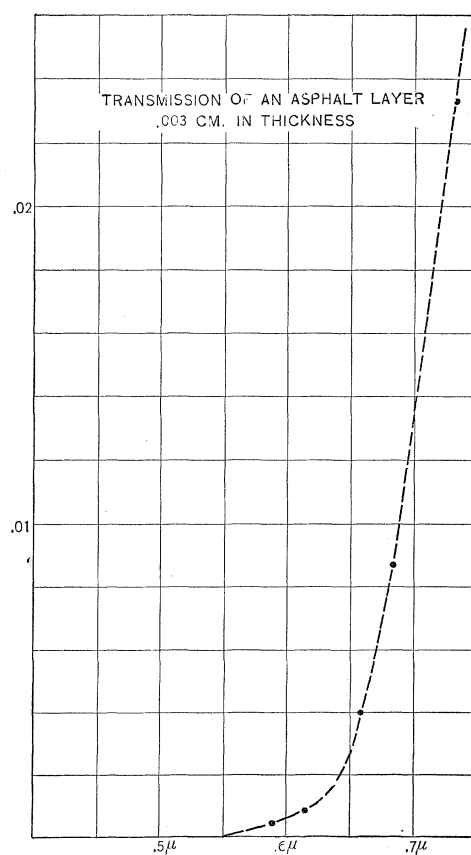


Fig. 2.

²To convert these coefficients into the extinction indices of Wernicke (Poggendorff's Annalen, Erg. Bd., 8, p. 67 [1877]), they must be divided by $\frac{4\pi}{\lambda}$, where λ is expressed in centimeters.

region of the *D* line being less than .0004 of the incident light; also that the transmission of yellow light is less than two per cent. of the transmission of the full red of wave-length $.73 \mu$. The opacity of this film was too great to permit of the location of the position of the maximum of the absorption band and measurements were accordingly made upon much thinner layers, prepared in the following manner. A cell having the form of a hollow wedge with sides of plane glass was filled with asphalt varnish and then emptied of what could be poured out and immediately inverted and left to dry with its mouth resting upon a sheet of filter paper and the apex of the wedge uppermost.

The downward flow of the slowly drying film of asphalt gave in this case a regular gradation to the layer which at the top of the cell was so thin as to show scarcely any color, while at the bottom it was nearly opaque. The light transmitted by this cell with its double layer of asphalt at distances of 2.5 cm. and 6.5 cm. from the apex was then compared spectrophotometrically with that transmitted by an uncoated cell made of the same glass.

The color of this layer was a red, changing gradually to a pale amber, tending at the apex to a greenish yellow; indeed the variation of color with thickness might be likened to that of a dichoric liquid.

A comparison of the transmission of the two portions of these films subjected to measurement showed the substance to be optically perfect, or at least not appreciably turbid. That is to say the relation

$$\frac{n}{m} \log \frac{I_0}{I_m} = \log \frac{I_0}{I_n},$$

where *n* and *m* were the relative thicknesses in the regions measured was found to be approximately true. The ratio $\frac{n}{m}$ was determined from the distances from the apex of the wedge of the two regions, under the assumption that the films were themselves wedge-shaped, tapering uniformly towards the apex. The agreement which was at least as close as my knowledge of the relative thicknesses, was however not sufficient to establish this fact completely and measurements were accordingly made upon two layers of different thick-

nesses placed upon glass plates in a manner similar to that employed in the specimen used in obtaining the data given in Table I. The relation of transmission to thickness in this case also was found to fulfill the law for optically perfect media with a degree of approximation equal to that of my knowledge of the thickness of the films.

It was found that while each pair of films was comparable in this respect between themselves, the sets could not be compared with one another and that neither gave correct values when compared

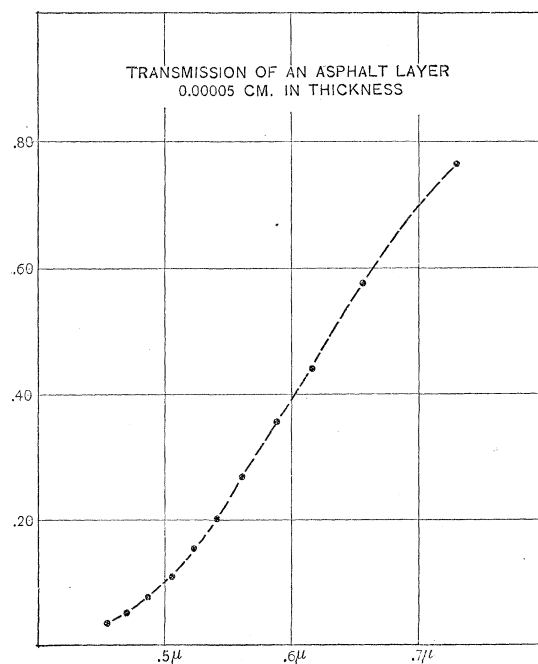


Fig. 3.

with the film of Table I. This discrepancy was due to the fact that the thickness of such films continues to diminish for a long time after they appear to be dry.

The two last mentioned films, for example, measured with the micrometer gauge about twenty-four hours after deposition, were found to be .0122 cm. and 0.0069 cm. in thickness. The next day they had fallen to 0.0026 cm. and 0.0009 cm. respectively. The

effective thickness of the former, computed from its transmitting power, in terms of that of the film of Table I., which had been measured after drying for several weeks was however only .00195 cm.

The extinction coefficients in Table I. refer to films which have been thoroughly dried and not to freshly deposited layers of asphalt varnish.

The thinner region of the double, amber-colored film near the apex of the wedge-shaped cell would have had a thickness when dry of only 0.000055 cm.

The transmission curve of this region (thickness 0.000055 cm.) is given in Fig. 3, from which it will be seen that the transparency was still diminishing at wave-length 0.45μ . The maximum of the absorption band must therefore lie at some still shorter wave-length; perhaps in the ultra-violet.

THE ANOMALOUS DISPERSION OF ASPHALT.

In order to determine the dispersion of asphalt for those wave-lengths for which it is transparent a prism was made by placing some fragments of solid asphaltum between two plane-parallel pieces of glass and heating carefully in a gas oven until the asphaltum began to flow, when the plates were firmly pressed together at one edge. After many trials a prism of small angle was thus obtained thin enough to transmit red, yellow and a trace of green light near its edge.

This was set up, as nearly at minimum deviation as possible in the path of the dispersed rays of a spectrometer with two prisms and the displacement of four bright lines was carefully measured.

The source of light was an electric arc plentifully supplied with lithium and sodium.

The angle of the prism was $1^\circ 50' 2''$.

The results of these measurements are given in Table II.

TABLE II.
Dispersion of a prism of asphalt.

Wave-lengths.	Index of Refraction.
Li ($\lambda = 0.6708\mu$)	$n = 1.6209$
Li ($\lambda = 0.6104\mu$)	$n = 1.6282$
Na ($\lambda = 0.5896\mu$)	$n = 1.6351$
Na ($\lambda = 0.5682\mu$)	$n = 1.6339$

It will be seen that anomalous dispersion begins to manifest itself between the yellow and green. It was not possible to make measurements at shorter wave-lengths by this method on account of the opacity of the material.

MEASUREMENTS IN THE INFRA-RED.

The transmitting power of asphalt in the infra-red was studied by interposing alternately the coated portion and the uncoated portion of a strip of glass, prepared like that used in the measurements given in Table I., in the path of the rays from an acetylene flame and comparing the deflections of a Nichols radiometer exposed to the absorption spectra thus obtained with the deflections produced by the spectrum of the uninterrupted rays from the flame. The

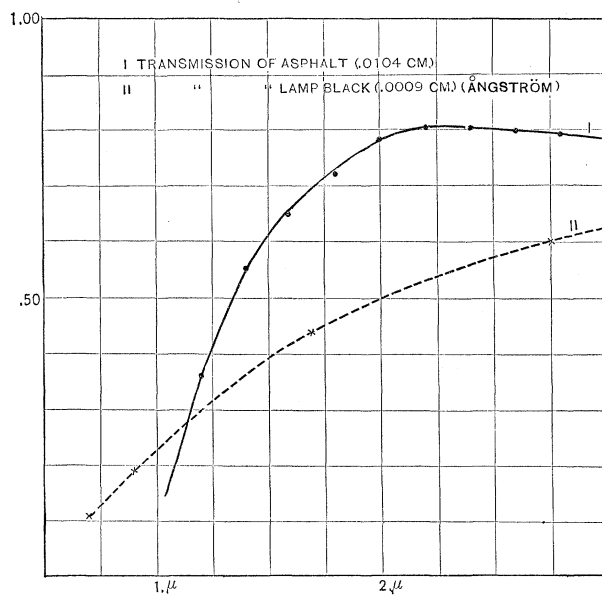


Fig. 4.

apparatus used was one employed by Mr. W. W. Coblentz in measurements of the absorption of solutions of iodine the results of which have not yet been published. It consisted of a mirror spectrometer with bisulphide prism, the radiometer being mounted in place of the eye piece so that its vanes would receive radiation of any desired

wave-length. From the observations upon the absorption in the coated and in the uncoated glass the absorption of the asphalt alone was computed. The measurements extended over the range of wave-lengths from 1.0μ to 2.8μ . The transmission increased rapidly from zero at 1.0μ to about .80 at 2μ , beyond which only slight changes in the transparency of the film were noted. There is apparently a slight maximum of transmitting power in the region 2.2μ . Measurements could not be carried with the apparatus used beyond 2.8μ on account of the rapidly increasing opacity of glass and carbon bisulphide, and on account of the small dispersion of the bisulphide prism for the greater wave-lengths. In order to extend the investigation to the still longer wave-lengths of the infra-red spectrum it would be necessary to repeat the measurements by means of layers of asphalt placed upon a plate of fluorite or rock salt and to make use of a prism of similar material in the spectrometer.

The results of these measurements are given in Table III. from the data contained in which the transmission curve shown in figure 4 is plotted. The thickness of the film employed was 0.010 cm. Its opacity was so complete that the disk of the sun could not be distinguished through it.

TABLE III.

Transmission of an asphalt film (0.010 cm. in thickness) in the infra-red.

Wave-length.	Transmission.	Extinction Coefficient.
1.0	.000	—
1.2	.333	104.
1.4	.550	59.8
1.6	.644	44.0
1.8	.718	33.2
2.0	.786	24.1
2.2	.809	21.2
2.4	.805	21.7
2.6	.791	23.4
2.8	.788	23.8

CONCLUSIONS.

There is much about the optical behavior of asphalt to suggest that its color may be due to the presence of carbon particles dissolved or perhaps suspended in some other medium, but the differences

between the two substances are scarcely less striking than their resemblances. We find the same transition from opacity, to transparency and this change occurs in the same region. For purposes of comparison, a portion of one of the curves given by Knut Ångström in the paper already cited has been inserted in Fig. 4. It is the transmission curve for a layer of lampblack the thickness of which was estimated at .0009 cm. in thickness. There is no significance in the comparison of a layer of asphalt with that of lampblack as regards thickness. It has been shown both by Rosicky¹ and by Stark² that lampblack obtained by smoking glass in the flame of a candle is of very loose structure, being equivalent to a layer of solid carbon of not more than three or four hundredths of the thickness. Ångström's values are therefore not strictly comparable with that computed for asphalt. It will be seen however that the change from opacity to transparency in the asphalt layer is much more abrupt than is the case with lampblack and that the former is more nearly transparent in those portions of the infra-red included in my measurements. A layer of lampblack .01 cm. in thickness would for example transmit only about .09 of the incident radiation of the wave-length $2\ \mu$. Asphalt of the thickness of Ångström's layer of lampblack would on the other hand transmit .98. It has been shown by Wood³ in a recent paper that lampblack exhibits anomalous dispersion in the visible spectrum and in this respect the two substances therefore have similar properties. The maximum of the absorption band for carbon lies in the case of some varieties of lampblack and also of layers of carbon deposited in vacuo as, for example, upon the inner surface of the bulb of incandescent lamps, in the brightest part of the visible spectrum.⁴ The measurements by Rosicky and by Stark seem to indicate however that in some specimens the center of the absorption band must lie further towards the violet.

That the coloring matter in asphalt varnish consists of minute particles, possibly of carbon, which are held in suspension by the liquid may be shown by means of the following experiment :

¹ Rosicky, Wiener Berichte, 78, II., p. 407 (1878).

² Stark, Wiedemann's Annalen, 62, p. 351.

³ Wood, Philosophical Magazine, 6, Vol. 1, p. 405 (1901).

⁴ Nichols and Blaker, PHYSICAL REVIEW, Vol. XIII., p. 378.

If a wire ring be dipped into the varnish and withdrawn it carries with it a flat film of liquid, which is very similar to a soap film in appearance. The coloring matter in this film is not uniformly distributed, as in a solution, but tends to gather into streaks and patches as if by capillary action, and it is very speedily drawn to the boundaries of the film leaving a layer which shows only the colors of interference. Upon drying it leaves behind a nearly colorless sheet of resinous material.