

being made for temperature, the determination of the currents by this method was abundantly accurate and very simple.

The results are grouped in three series, of which the first two were considered in the Preliminary Note. In both of them the same tube was used, the principal difference being that in the first the light traversed the tube three times, and in the second but once. In the third series another tube was employed, and some improvements in respect to thermal insulation were introduced. The readings were taken with a double image prism in place of the ordinary analysing nicol, a substitution by which it is believed some advantages were obtained.

From the fifteen sets of observations of Series I, we find as the rotation of sodium light in bisulphide of carbon at  $18^{\circ}$  corresponding to a difference of potential equal to unity C.G.S. the value  $\cdot 04203$  minute. From the four observations of Series II we get in like manner  $\cdot 04198$  minute, and from the seven observations of Series III  $\cdot 04202$  minute. The last value is adopted as the most probable.

In an appendix some remarks are made upon polarimetry in general, especially in relation to the half-shade method. A device proposed by M. Becquerel for augmenting the precision with which rotations can be determined with the aid of a half-wave plate is considered, and the conclusion is arrived at that no advantage can thus be obtained.

### III. "Absorption-spectra Thermograms." By Captain ABNEY, R.E., F.R.S., and Colonel FESTING, R.E. Received December 31, 1884.

When employing a grating for visual work, the choice of a medium which shall absorb the overlapping parts of orders of the spectrum other than that under examination is a comparatively simple affair. When working photographically, however, it becomes necessary to know what invisible rays the medium will cut off. For instance, in investigations in the infra-red of the spectrum, we have found it necessary to ascertain whether media which absorb the blue and allow the red rays to pass would also transmit the above-mentioned parts of the spectrum.

Photography would seem to be the simplest method of experimenting in this direction; but the results not being quantitative, as are those obtained by a thermopile, we found it better to work with that instrument.

It should be remembered that we were dealing with the infra-red part of the spectrum, in which the energy is so great as to be well shown by the thermopile; in the more refrangible part the indications

of the thermopile are so feeble that photography would be more serviceable.

The absorbing media usually used were :—

1. A solution of potassium dichromate.
2. Ruby glass combined with orange glass.
3. Deep orange glass alone (often called “stained red”).
4. Iodine dissolved in an aqueous solution of potassium iodide.
5. Iodine in alcohol.
6. Iodine in carbon disulphide (the violet rays being absorbed by canary glass).
7. Dyes of different kinds, combined with coloured glasses.
8. Deep coloured cobalt glass and orange glass.

Of these the 1st and 3rd were employed when the green rays had not to be cut off; the 2nd, 4th, and 5th when the whole of the more refrangible end of the spectrum down to the orange had to be absorbed, while the 6th cut off very nearly the whole of the visible spectrum. The dyes employed were soluble in either alcohol or water.

With No. 8 (deep cobalt and orange glasses) a very long exposure to the dark rays was found necessary to obtain a satisfactory impression on a sensitive plate.

In these experiments we used the thermopile described in our paper in the “Proc. Roy. Soc.” (No. 232, 1884). The source of radiation was an incandescence lamp maintained by a Grove’s battery of 40 cells, the filament being approximately at the temperature of  $1650^{\circ}$ .

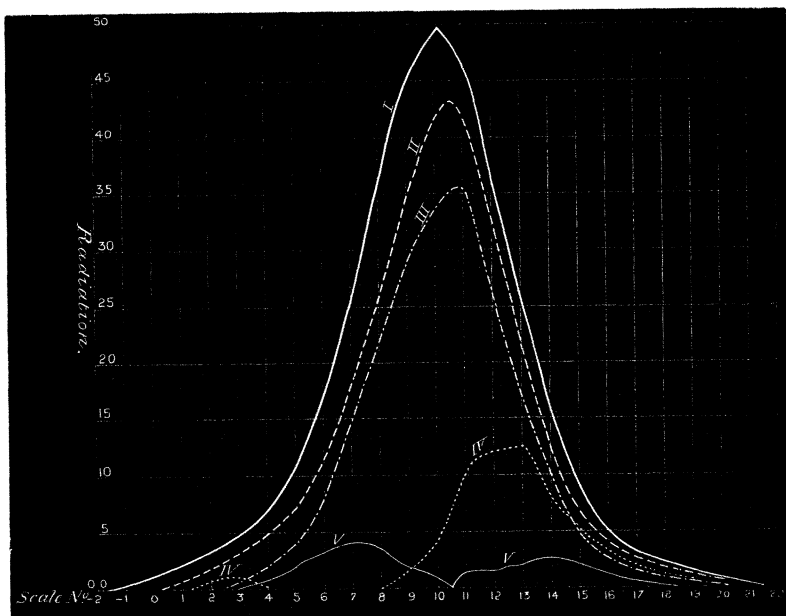
An image of the filament was thrown by a lens on the slit of a collimator, behind which was the dispersing prism. The rays emerging from this were collected by a second lens into a spectrum at a definite distance from the prism, and the thermopile was passed along this spectrum, as described in our paper above mentioned. The absorbing media were placed in front of the slit of the collimator, glass cells one-eighth of an inch of internal thickness being used for containing the liquids.

The thermogram of the radiation unabsorbed, except by the prism and lenses, was first made (see Curve I, figs. I and II). An empty cell was next placed in front of the slit; the thermogram (Curve VI, fig. II) shows that no special, but a general absorption has been produced.\* A comparison of Curves II, III, and V with Curve I, in fig. I, shows the absorption of radiant energy by orange glass, ruby glass, and cobalt glass respectively.

Through the kindness of Messrs. Chance Brothers we can state that the orange colour is given by the oxides of silver and antimony combined, whilst the ruby colour is due to cuprous oxide. The

\* The empty cell-curve has been corrected for reflection from the two inner surfaces of the glass, so that all comparisons are made under similar conditions.

FIG. 1.



- Curve I. Naked incandescence lamp.  
 Curve II. Absorption of orange glass.  
 Curve III.       "       ruby       "  
 Curve IV.       "       green     "  
 Curve V.       "       dark cobalt glass.

cobalt colour, as is well known, is given by cobalt. A glance at the curves shows why any combination in which the last is employed would necessitate a prolonged exposure, as it will be seen that it entirely absorbs the infra-red rays about the part of maximum energy. The use of this glass should therefore be avoided, if possible, when the infra-red rays are to be used in photography.

In a paper by Captain Abney, which appeared in the "Philosophical Magazine" (vol. x, 1880), it was shown that reversal of the photographic image was caused by rays of low refrangibility. If a photographic plate which has been exposed to white light in the camera be subsequently exposed to radiations of low refrangibility, as for instance to light passing through a combination of ruby and orange glass, we should expect that there would be a gradual extinction of the effect of the white light. This is true in practice, though it rarely happens that the after exposure to such radiation is sufficiently prolonged to be hurtful. A case, however, might arise when a knowledge—or perhaps it

should rather be said an appreciation—of this fact would be of practical use. In such a case the visible radiation coming through a combination of cobalt and orange glass might be successfully employed.

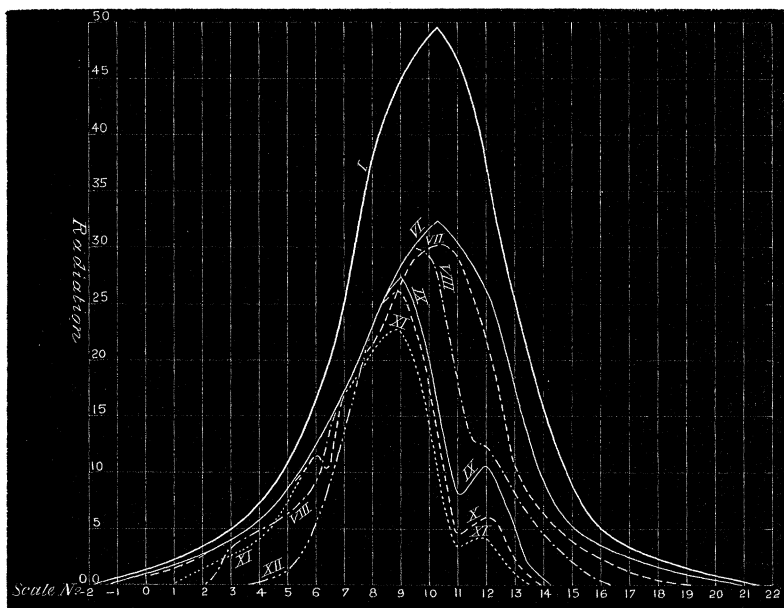
Curve IV is the absorption-spectrum thermogram of a green glass, which obtains its colour from a combination of cupric oxide and iron oxides. An examination of the prismatic spectrum photographed through such glass has led us to suspect that green glass is transparent to certain rays of very low refrangibility. The thermogram fully confirms this. Some four years ago one of us proposed to the Meteorological Committee of the Royal Society the use of green glass for thermometer bulbs, in the belief that it totally absorbed the infra-red rays. This is now found to be a mistake, and some other colouring matter must be sought for for this purpose.

Fig. II illustrates some interesting facts in connexion with absorption. Curves I and VI, as already stated, are the thermograms of the lamp without and with an empty glass cell in front of the slit. Curve VII is the absorption thermogram of benzene. As far as Scale No. 6 there is no appreciable absorption, but from that point there is a drop in the curve, which proves to be coincident with the radical band of the group of benzene compounds, which we mapped photographically (see "Phil. Trans.," 1882). At a point between 7 and 8 on the scale absorption again commences, and although of some small extent, is appreciable as far as the end of the thermogram, thermal action being traceable nearly down to Scale No. 20, or wavelength 27,000. This point we presume to consider of some importance, for we have shown that there is reason to believe the existence of some compound of the aromatic series between us and the sun, as the radiant band is coincident with a very strong line in the solar spectrum. The solar spectrum as determined by the thermopile being coterminous in this direction with that of the incandescence lamp, had it been found that benzene cut off the lower part of the latter, our belief as to the indications of benzene in the solar spectrum would have been much shaken.

Curve VIII is the thermogram of a deep-coloured solution of iodine in alcohol. This terminates near Scale No. 16. We found a slight dip near Scale No. 6; this was too slight to be conveniently shown on the diagram. It is coincident in position with the alcohol radical band. The thermogram of uncoloured alcohol is the same as that of Curve VIII, with the exception that some further thermal action in the visible part of the spectrum has to be registered.

Curve IX is the thermogram of the absorption-spectrum of a saturated solution of common salt in water. Rock salt, as is well known, allows nearly all radiation to pass, and it seemed desirable to ascertain what effect it would have in solution. The effect of the salt appears to have been a mitigation of the absorptive power of the

FIG. 2.



Curve I. Naked incandescence lamp.

Curve VI. Absorption of empty cell.

Curve VII. " of cell and  $\frac{1}{8}$ -inch of benzene.

Curve VIII. " "  $\frac{1}{8}$ -inch iodine solution in alcohol.

Curve IX. " " " sodium chloride saturated solution in water.

Curve X. " " " water.

Curve XI. " " " iodine in an aqueous solution of potassium iodide.

Curve XII. " " " iodine in carbon disulphide.

water, as the curve shows the same qualitative absorption as Curve No. 10, which is that due to  $\frac{1}{8}$ -inch of water, the absorption being equivalent to what would have been produced by a diminished thickness of water. This is a fact of some importance theoretically, and has been confirmed by experiments with other solutions.

Curve XI is that due to the absorption of iodine in an aqueous solution of potassium iodide. Compared with Curve X it shows that the molecular structure of potassium iodide is such that it intensifies the absorption due to water alone, no trace of the spectrum being found beyond Scale No. 14.

Curve XII is the thermogram of the absorption-spectrum of a solu-

Scale Number.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Curves.
	Naked light.	Orange glass.	Ruby glass.	Green glass.	Dark cobalt glass.	Empty glass cell.	Benzene.	Iodine in alcohol.	NaCl in water.	Water.	Iodine in potassium iodide and water.	Iodine in carbon disulphide.	Approximate wavelengths.
-1	0	0	0	0	0	0	0	0	0	0	0	0	5500
0	1	0	0	0	0	0	0	0	0	0	0	0	5850
2	3	1 $\frac{1}{2}$	0	0 $\frac{1}{2}$	0	2 $\frac{1}{2}$	2 $\frac{1}{2}$	0	2 $\frac{1}{2}$	2 $\frac{1}{2}$	0 $\frac{1}{2}$	0	6500
3	..	..	..	1	0	..	..	3	..	2 $\frac{1}{2}$	..	0	6850
4	7	4 $\frac{1}{2}$	1 $\frac{1}{2}$	0	0	5 $\frac{1}{2}$	5 $\frac{1}{2}$	3	5 $\frac{1}{2}$	5 $\frac{1}{2}$	4	0 $\frac{1}{2}$	7250
5	11	7	4	0	2	8	8	6	8	8	7	1 $\frac{1}{2}$	7750
6	17	11	8	0	3	12	11 $\frac{1}{2}$	9	12 $\frac{1}{2}$	12 $\frac{1}{2}$	12 $\frac{1}{2}$	6	8400
6 $\frac{1}{2}$	..	..	..	0	..	..	11	..	..	..	..	..	8800
7	27	17	15	0	4	17 $\frac{1}{2}$	17 $\frac{1}{2}$	17 $\frac{1}{2}$	17 $\frac{1}{2}$	17 $\frac{1}{2}$	17	14	9200
8	37 $\frac{1}{2}$	25	22	0	3 $\frac{1}{2}$	24	22	24	24	24	21	24	10100
9	45	35	29	1 $\frac{1}{2}$	2	29	28	29	27 $\frac{1}{2}$	26 $\frac{1}{2}$	22	29	11250
10	49	42	34	4	1	32	30	29	19	18	13	32	12500
10 $\frac{1}{2}$	48 $\frac{1}{2}$	43	35 $\frac{1}{2}$	..	0	31 $\frac{1}{2}$	30	..	..	..	..	31 $\frac{1}{2}$	13200
11	46 $\frac{1}{2}$	42	35 $\frac{1}{2}$	10	1 $\frac{1}{2}$	30 $\frac{1}{2}$	29	18	8	4 $\frac{1}{2}$	3 $\frac{1}{2}$	30 $\frac{1}{2}$	13900
11 $\frac{1}{2}$	..	..	..	..	..	..	..	13	9 $\frac{1}{2}$	5	4	..	14600
12	35 $\frac{1}{2}$	32	25 $\frac{1}{2}$	12	1 $\frac{1}{2}$	26	21	12 $\frac{1}{2}$	10 $\frac{1}{2}$	6	4	..	15300
13	25	21	17	12 $\frac{1}{2}$	2	17	12	8	5	3	1 $\frac{1}{2}$	17	16800
14	15 $\frac{1}{2}$	12	10	5 $\frac{1}{2}$	2 $\frac{1}{2}$	9	6 $\frac{1}{2}$	4 $\frac{1}{2}$	0 $\frac{1}{2}$	0	0	9	18300
15	9	7	5	3 $\frac{1}{2}$	1 $\frac{1}{2}$	5 $\frac{1}{2}$	4	0 $\frac{1}{2}$	2	0	0	5 $\frac{1}{2}$	19800
16	2	4	2 $\frac{1}{2}$	1	11	4	2	0	0	0	0	4	21300
18	2	1 $\frac{1}{2}$	1	1	0 $\frac{1}{2}$	1	0 $\frac{1}{2}$	0	0	0	0	1 $\frac{1}{2}$	24500
20	0 $\frac{1}{2}$	0 $\frac{1}{2}$	0	0 $\frac{1}{2}$	0	0 $\frac{1}{2}$	0	0	0	0	0	0 $\frac{1}{2}$	27000

tion of iodine in carbon disulphide. It differs from the curve due to the empty cell only in the visible and shortest wave-length portion of the invisible spectrum, as might be expected. We have also examined plain carbon disulphide and carbon tetrachloride, but have found only small traces of absorption with these liquids.

We have found that alum solution gives a curve which differs but little from No. XI in the least refrangible part of the spectrum; the alum seems to intensify the absorptive power of the water in which it is dissolved. It has been so often stated that an alum solution cuts off all rays of low refrangibility (or as it is incorrectly and commonly said, all "heat rays") that we were not prepared for the comparatively small effect that it produces. It may be said that, roughly, one thickness of a saturated solution of alum in water is equivalent to a double thickness of water, and not more. Judging by the thermograms, even this would be an exaggeration of the truth; but the use of glass in the cells, prisms, and lenses diminishes the effect as found when the total radiation is taken directly.

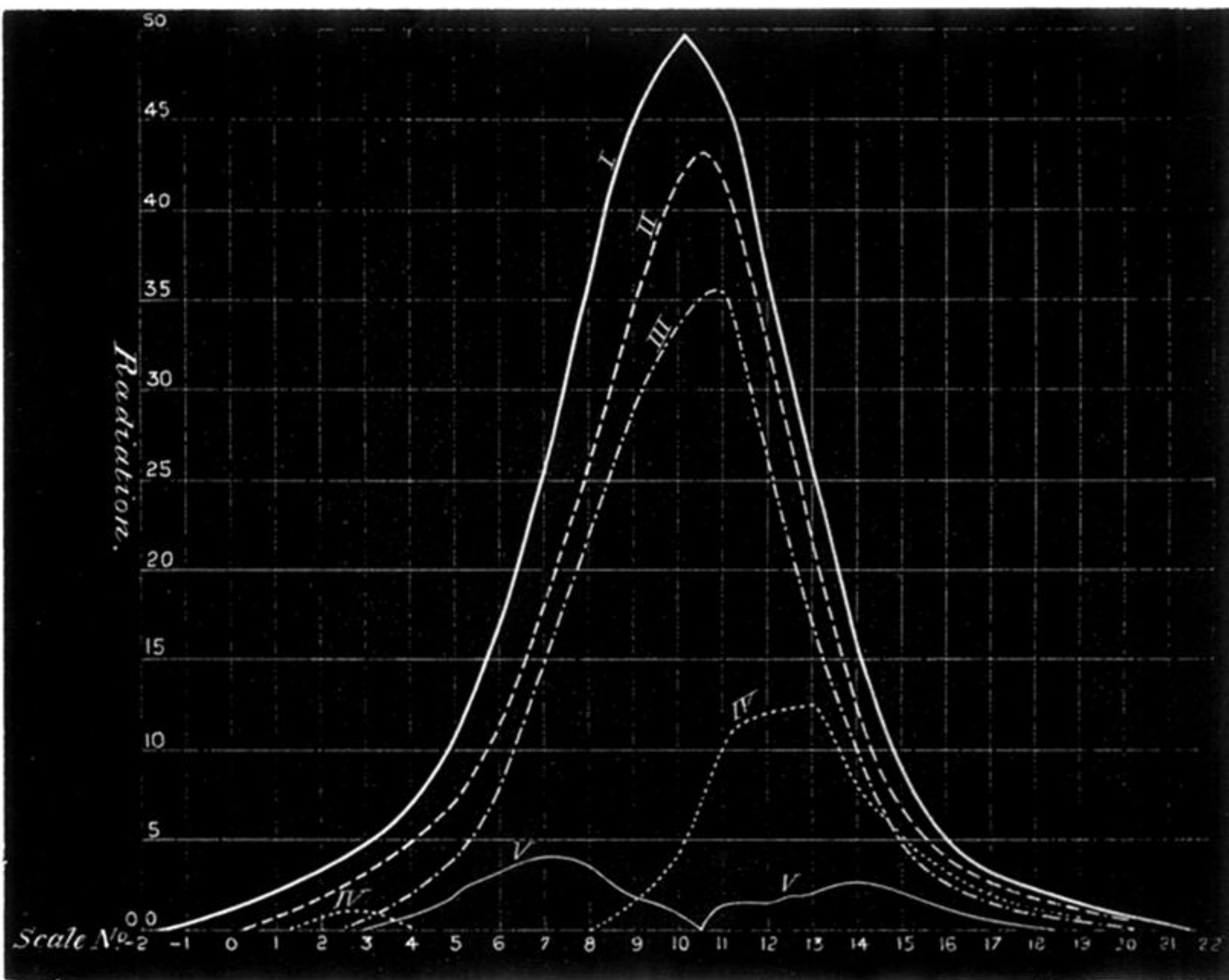
We may add that dyes seem only to absorb in the visible spectrum, and to have but little, if any, action in the invisible regions.

The positions which we assign to the maxima of energy in the different absorption spectra of glasses do not agree with those that have been published; but as ours are the result, not of one set of experiments, but, in some cases, of dozens, we feel fairly confident as to their correctness.

IV. "Observations on the Upper Partial Tones of a Pianoforte String, struck at one-eighth of its Length." By ALFRED JAMES HIPKINS (of John Broadwood and Sons, London). Communicated by ALEXANDER J. ELLIS, F.R.S. Received January 7, 1885.

This is a postscript to my paper on the *harmonics* of such a string, read on the 20th of November, 1884. According to Professor Helmholtz's theories, the tone of a struck string is compounded of a number of *simple partial* tones, with the ratios of their frequencies as 1, 2, 3, 4, &c. The *harmonics* are themselves also *compound* tones of which the primes or lowest partials are the partials of the original tone. These are produced on damping the other partials by touching them at a node. Now, in my former paper, I showed that by so touching I could bring out twenty different harmonics of the string, and among these the 8th and 16th. Young's law, however, makes an harmonic impossible to produce, if its node is the point struck. Hence the string being struck at one-eighth of its length, no 8th or 16th

FIG. 1.



Curve I. Naked incandescence lamp.

Curve II. Absorption of orange glass.

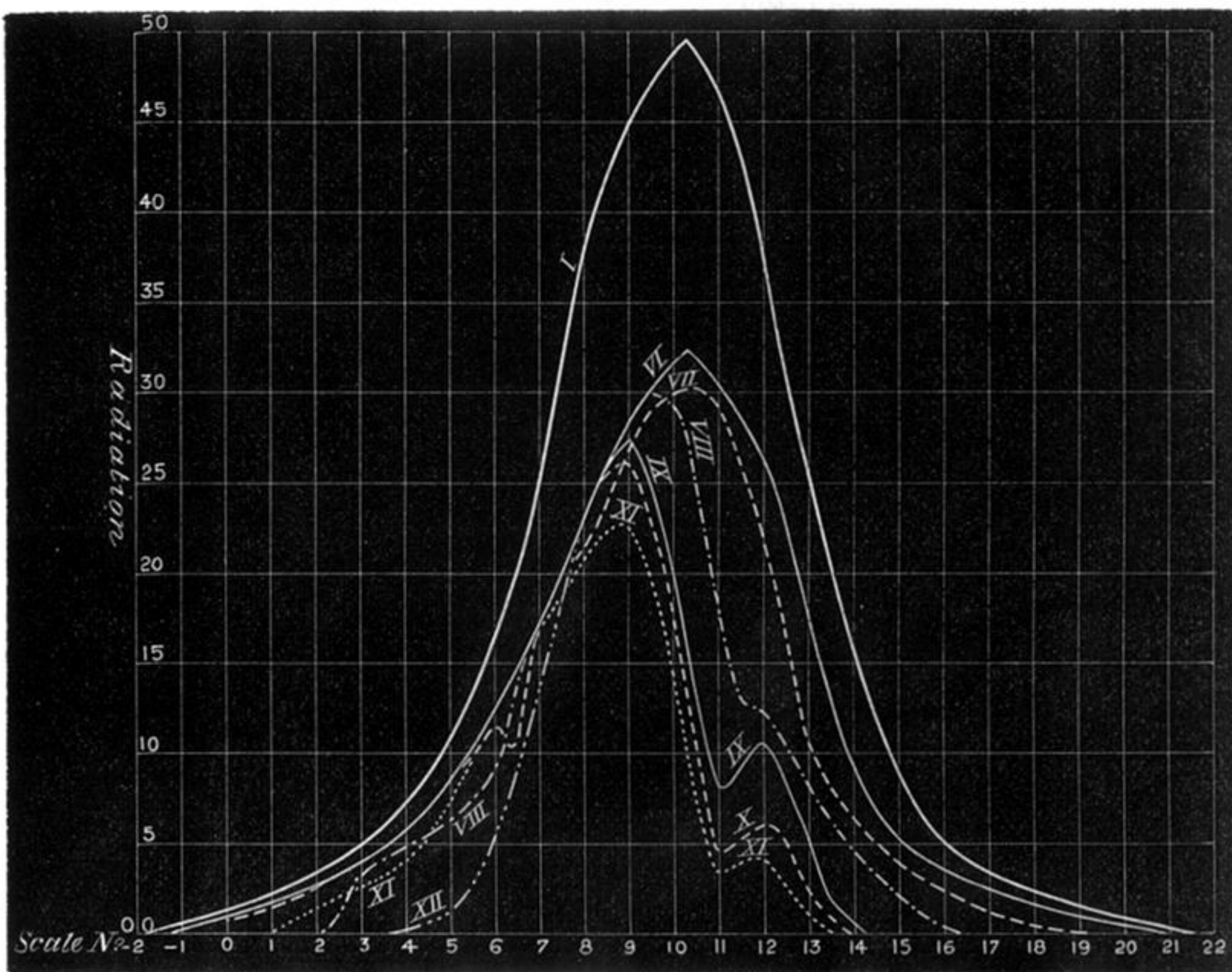
Curve III. " ruby "

Curve IV. " green "

Curve V. " dark cobalt glass.



FIG. 2.



- |       |       |  |
|-------|-------|--|
| Curve | I.    | Naked incandescence lamp.                                |
| Curve | VI.   | Absorption of empty cell.                                |
| Curve | VII.  | „ of cell and $\frac{1}{8}$ -inch of benzene.            |
| Curve | VIII. | „ „ $\frac{1}{3}$ -inch iodine solution in alcohol.      |
| Curve | IX.   | „ „ „ sodium chloride saturated solution in water.       |
| Curve | X.    | „ „ „ water.   |
| Curve | XI.   | „ „ „ iodine in an aqueous solution of potassium iodide. |
| Curve | XII.  | „ „ „ iodine in carbon disulphide.                       |