VII. *Photo-chemical Researches.*—Part V. *On the Direct Measurement of the Chemical Action of Sunlight.*

By Robert Bunsen, *For. Mem. R.S., Professor of Chemistry in the University of Heidelberg, and* Henry E. Roscoe, *B.A., Ph.D., Professor of Chemistry in Owens College, Manchester.*

Received November 11,—Read December 11, 1862.

The photo-chemical action exerted by direct sunlight and by diffuse daylight upon a horizontal portion of the earth's surface, varies with the time of year and with the latitude of the place, and constitutes an important link in the chain of physical relations which connects the organic with the inorganic world.

In former communications* made to the Royal Society we have endeavoured experimentally to determine the distribution of these chemical actions on the earth's surface, as varying with the time of day and year, and with the geographical position of the place, when the sky is perfectly unclouded. The methods of measurement there adopted are, unfortunately, not applicable to the determination of the variations in photo-chemical intensity when, as is most frequently the case, the transparency of the atmosphere is more or less obscured by clouds, mist, or rain. To enable us to estimate the alterations which occur in the amount of the chemically active rays falling on the earth's surface, we must, therefore, have recourse to a mode of measurement totally different from that employed in our former investigations.

In spite of the numerous futile attempts which have from time to time been made for the purpose of establishing a standard of measurement of the chemical action of light by means of photographic tints, it appeared to us not impossible in this way to gain the end we desired.

The proposals which have been made to register and measure the chemical action of light by help of photographic tints have been very numerous; amongst others we may mention those of Jordan, Hunt, Herschel†, and Claudet‡. All instruments based upon such principles must, however, afford totally unreliable results unless we know the conditions under which photographic surfaces of a constant degree of sensitiveness can be prepared, and unless the relations are determined which exist between the degree of tint produced and the time and the intensity of the light acting to produce such a tint.

Hence one of the first points of inquiry is, to determine whether the tints produced by the photographic action vary in shade in the direct ratios of the intensities of the incident light.

* Philosophical Transactions, 1857, pp. 355, 381, 601; 1859, p. 879.

† Ibid. 1840, p. 46.

‡ London, Dublin, and Edinburgh Philosophical Magazine, Ser. 3. vol. xxxiii. p. 329.

For the purpose of measuring the degree of tint which the paper assumed, we employed a circular disc with black and white sectors whose relation to one another could be altered at pleasure. By allowing the black sector to cover $\frac{1}{10}$, $\frac{2}{10}$, $\frac{3}{10}$, &c. of the surface of the disc, we obtained, on rotation, a disc having the tints $\frac{1}{10}$, $\frac{2}{10}$, $\frac{3}{10}$, &c. The central portions of the disk were filled with the papers which had been tinted by the action of the light. It was soon found that very slight differences in the degree of shade could be detected so long as the tints are light-coloured, but that when deeper tints are employed the eye loses the power of estimating such differences. Experiments thus made proved that the shade produced upon photographic paper is not proportional to the intensity of the incident light; thus the intensities 5 and 1 were found to correspond to the shades 0·5 and 0·22. Hence we have altogether relinquished the idea of employing any mode of measurement founded upon a comparison of photographic papers of *different* shades.

We next had to examine whether *equal* shades of blackness produced by light of different intensities acting for different times can be used as the basis of the mode of measurement, under the supposition that equal shades of blackness always correspond to equal products of the intensity of the incident light into the times of insolation. The truth of this proposition, which was assumed some years ago by MALAGUTI *, has recently been experimentally verified by HANKEL† within the slight variation of intensity from 1 to $2\frac{1}{2}$. In order to prove the truth of this proposition for the wider limits needed in our measurements, it was necessary to determine the times of insolation very exactly to within small fractions of a second, and to be able to estimate with accuracy the points of equal shade. These ends were gained by employing the following arrangement.

The iron stand (Plate IX. fig. 1) carries the metal plate (A), which can be placed horizontally by three set-screws, and in which a straight slit, 15 millimetres broad and 190 millimetres long, is cut. Over this slit, which is shaded black in the drawing, is placed a very thin and elastic sheet of mica *b c d*, blackened at one end from *b* to *c*, and fastened at *d* to the curved drum (E) attached to the pendulum (F). When the pendulum is allowed to vibrate, the sheet of mica as it rolls on and off the curved drum (E) at each vibration, uncovers and again covers the slit, so that each point throughout the whole length of the slit is exposed for a different period. If we wish to use this instrument for the purpose of exposing a photographic surface to the action of the light for different times, the paper is gummed upon the white surface of the metallic slide (G, fig. 1); this is then covered by a metallic lid, which does not touch the paper, and the whole arrangement pushed into the dark groove *h*, placed directly under the slit, and protected from the entrance of light by a lappet of cloth, which hangs in front. The metallic lid is then withdrawn, the screw *k* turned, and thus the paper slightly pressed against the slit, so that no light can enter sideways between the paper and the

* Ann. de Chim. et de Phys. tom. lxii. p. 5.

† "Messungen über die Absorption der chemischen Strahlen des Sonnenlichts," Abhandl. d. Kön. Sächs. Gesellschaft der Wissenschaften. Leipsig, 1862. Bd. ix. p. 55.

thin metallic edges of the slit. By raising the lever *n m l* at *l*, the pendulum is released from the catch at *m*, and, after completing a vibration, it is held fast by a lower catch at *n*. If it be required to double or to multiply the time of insolation, it is only necessary to repeat the vibration, once or several times, care being taken before each vibration to raise the rod of the pendulum so as to allow the end to fall into the upper catch. In order thus to set the pendulum in motion, and to stop it with certainty and ease, the lever is once for all balanced by a small weight at *l*, so that the arm *n m* is but slightly heavier than the arm *l*.

The time which the sensitized paper is insolated at any point on the slit can be obtained when we know the duration and the amplitude of vibration of the pendulum. Let α α (fig. 2) represent the end of the sheet of mica in the position in which it is found when the end of the pendulum is held in the upper catch *m*; let β β (fig. 2) represent the position of the end of the sheet of mica when the pendulum is freely hanging and in equilibrium; and let γ γ (fig. 2) be the position which the same end occupies during the vibration when the time t has elapsed since the start of the pendulum. If we call u the distance γ β, and τ the time during which the sensitized surface at $\gamma\gamma$ is insolated, the relation between u and τ is found as follows:—Let a represent the distance α β, and let T represent the duration of a simple vibration, we have

$$u=a\,.\cos\left(\frac{t}{\mathrm{T}}\pi\right).$$

If t_1 signify the time at which the end of the sheet of mica returns to the position γ γ, we have

$$t_1=2\mathrm{T}-t,$$

and also

$$\mathrm{T}=t_1-\frac{\tau}{2},$$

and therefore

$$\tau=2(\mathrm{T}-t);$$

or, if we express τ in terms of u,

$$\tau=\frac{2\mathrm{T}}{\pi}\left(\pi-\cos^{-1}\frac{u}{a}\right),$$

or

$$u=-a\cos\left(\frac{\tau}{2\mathrm{T}}\pi\right). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.)$$

In our instrument a=105 millimetres, and $\mathrm{T}=\frac{3}{4}$ second. From formula (1) a Table can easily be calculated, in which the time of insolation is given for every point on the slit; that is, the time for which, during one vibration of the pendulum, this point is uncovered by the blackened sheet of mica. For this purpose we have applied a millimetre scale, commencing at δ, to the slit, which in our instrument, reckoning from β β, extended 85 millims. in the direction of δ, and 105 millims. in the direction of ε (fig. 2). Column I. of the following Table contains the numbers of the millimetre scale, and column II. the corresponding times of insolation for one vibration expressed in seconds.

TABLE I.

I. Millims.	II. Seconds.	I. Millims.	II. Seconds.	I. Millims.	II. Seconds.	I. Millims.	II. Seconds.	I. Millims.	II. Seconds.	I. Millims.	II. Seconds.
0	1·200	32	1·003	64	0·846	96	0·700	128	0·549	160	0·369
1	1·193	33	0·998	65	0·841	97	0·695	129	0·544	161	0·363
2	1·186	34	0·993	66	0·837	98	0·691	130	0·539	162	0·357
3	1·179	35	0·988	67	0·832	99	0·686	131	0·534	163	0·350
4	1·172	36	0·983	68	0·828	100	0·682	132	0·528	164	0·343
5	1·165	37	0·977	69	0·823	101	0·677	133	0·523	165	0·336
6	1·158	38	0·972	70	0·819	102	0·672	134	0·518	166	0·329
7	1·151	39	0·967	71	0·814	103	0·668	135	0·513	167	0·321
8	1·144	40	0·962	72	0·809	104	0·663	136	0·508	168	0·314
9	1·137	41	0·957	73	0·805	105	0·659	137	0·502	169	0·309
10	1·131	42	0·952	74	0·800	106	0·654	138	0·497	170	0·300
11	1·125	43	0·947	75	0·796	107	0·650	139	0·492	171	0·291
12	1·119	44	0·942	76	0·791	108	0·645	140	0·487	172	0·283
13	1·113	45	0·937	77	0·786	109	0·640	141	0·482	173	0·274
14	1·106	46	0·932	78	0·782	110	0·635	142	0·476	174	0·266
15	1·100	47	0·927	79	0·777	111	0·631	143	0·470	175	0·257
16	1·094	48	0·922	80	0·773	112	0·626	144	0·465	176	0·249
17	1·087	49	0·917	81	0·768	113	0·621	145	0·459	177	0·240
18	1·081	50	0·912	82	0·764	114	0·617	146	0·453	178	0·229
19	1·076	51	0·907	83	0·759	115	0·612	147	0·448	179	0·219
20	1·070	52	0·903	84	0·755	116	0·607	148	0·442	180	0·208
21	1·064	53	0·898	85	0·750	117	0·603	149	0·436	181	0·198
22	1·058	54	0·893	86	0·745	118	0·598	150	0·431	182	0·187
23	1·053	55	0·888	87	0·741	119	0·593	151	0·425	183	0·176
24	1·047	56	0·884	88	0·736	120	0·588	152	0·419	184	0·161
25	1·041	57	0·879	89	0·732	121	0·583	153	0·413	185	0·146
26	1·036	58	0·874	90	0·727	122	0·578	154	0·407	186	0·131
27	1·030	59	0·870	91	0·723	123	0·573	155	0·401	187	0·116
28	1·025	60	0·865	92	0·718	124	0·568	156	0·394		
29	1·019	61	0·860	93	0·714	125	0·563	157	0·388		
30	1·014	62	0·856	94	0·709	126	0·558	158	0·382		
31	1·009	63	0·851	95	0·704	127	0·553	159	0·376		

The paper insolated in the slit whilst the pendulum is vibrating, exhibits throughout its whole length a regularly diminishing shade. In Table I. the time of insolation for each one of these different shades is to be found.

If we wish to determine which of these shades on the strip of paper corresponds to another tint produced by a separate insolation, we cannot make the comparison of the two shades either by daylight or by lamp- or candle-light, as the weakest light of this kind, which must be used in order to make such a comparison accurately, produces a sensible alteration in the tint of the paper during the process of reading. Still less does it appear advisable to fix the paper with hyposulphite of soda, or other material, before comparison, as such a treatment frequently causes irregular alteration of tone. We have overcome this difficulty by employing an intense soda-flame for illuminating the surfaces to be compared. This light is chemically so inactive that the rays proceeding from the flame can be concentrated by a convex lens and allowed to fall for several hours upon the sensitized paper without producing the least change of colour. This mode of illumination possesses another important advantage, inasmuch as small differences in colour, which render the comparison of shades by the eye with ordinary white light so difficult, entirely disappear when the monochromatic soda-flame is employed.

In order to avoid the necessity of carrying the instrument into the dark after each insolation, a millimetre scale, similar to the one upon the slit, is fastened upon a wooden board (fig. 3, *a*) covered with paper, and moveable in a groove across a fixed wooden stand. The strip of photographically tinted paper is then cut off from the slide G and gummed upon the board (*a*, fig. 3), so that it has the same position relative to the scale on the board as it had to the scale on the slit. A, fig. 4 represents a small square wooden block having a circular hole in the middle 5 to 6 millims. in diameter, the lower half being covered by the paper of which the degree of shade has to be determined. This block is pressed by means of a spring, as is seen in fig. 3, in a fixed position against the strip of paper. On throwing the image of the soda-flame C, by help of the convex lens D, upon the circular opening in the block, it is easy, by drawing the slide backwards and forwards, to determine the exact point at which the upper and lower halves of the circular hole appear equally dark. It is then only necessary to read off on the scale the number representing the time which the paper at that point has been insolated in order to determine the degree of shade which the paper in that time has attained. To ensure accuracy in the observations, it is necessary that the eye should always be placed in one and the same position; most advantageously in a direction nearly perpendicular to the surface of the strip of paper.

Having proved by experiment with the above instrument that we were able to measure the length of time required to effect equal degrees of shade within hundredths of a second, it became necessary to obtain a series of lights of accurately known degrees of intensity, and varying as much as possible from each other, in order to produce various shades on photographic paper. We employed for this purpose direct sunlight, and in the following manner we avoided any errors arising from the varying intensity of the light caused by the alteration of the sun's zenith-distance, and the changes of transparency in the atmosphere. In the roof of the darkened loft of the laboratory at Heidelberg, a brass plate was inserted, in which were bored round holes varying in size, and countersunk from the outside. The diameters of these holes were accurately measured with a micrometer, and through the holes sunlight was allowed to fall upon the sensitized paper, the surface of which was placed perpendicularly to the incident rays, and at such a distance from the brass plate that, seen from this position, the holes presented a smaller apparent diameter than the sun. The several intensities of the small pictures of the sun thrown upon the paper, which were so well defined that the larger solar spots were distinctly seen, are thus obtained quite independently of any alteration which change in the height of the sun, or variation in the transparency of the air may produce, and are directly proportional to the areas of the openings through which the light passes.

By allowing these pictures of the sun having the intensities I_0, I_1, I_2..., to act upon the paper for the times t_0, t_1, t_2, the products I_0t_0, I_1t_1, I_2t_2 were obtained for the various tints thus produced. A second piece of the same photographic paper was then exposed to diffuse daylight, of the intensity i, in the pendulum-instrument, and thus a tinted strip was produced containing a successive gradation of shade. For each particular shade the time of insolation τ_0, τ_1, τ_2 could be read off on the scale, and hence the products $i\tau_0$, $i\tau_1$, $i\tau_2$, &c. could be formed. The points upon the strip were next determined (by reading off with the soda-flame) which corresponded in shade to the several tints produced by the sun-pictures. On the supposition that equal products of intensity into time of insolation correspond to equal shades of blackness, we have the following equations:—

$$I_0t_0=i\tau_0,$$

$$I_1t_1=i\tau_1,$$

and

$$\frac{I_0}{I_1}=\frac{t_1\tau_0}{t_0\tau_1};$$

or, if we take a special case,

$$\tau_1=t_1I_1 \,.\, \text{const.} \qquad (2.)$$

The following experiments prove that this equation is satisfied.

Experiment I.

8th August 1860, at 12h 30m P.M. Cloudless sky.

I. I.	II. t.	III. τ. Observed.	IV. τ. Calculated.	V. Difference.
1·00	20″	2·55″	2·47″	−0·08″
1·69	20	4·06	4·17	+0·11
2·78	20	7·01	6·86	−0·15
4·00	20	9·92	9·87	−0·05
5·44	20	13·46	13·43	−0·03
7·47	20	18·26	18·44	+0·18

Experiment II.

2nd August 1862, at 12h 11m P.M. Cloudless sky.

I. I.	II. t.	III. τ. Observed.	IV. τ. Calculated.	V. Difference.
1·00	150″	4·53″	4·75″	+0·22″
1·71	150	8·71	8·15	−0·56
36·81	10	11·62	11·66	+0·04
45·04	10	14·08	14·28	+0·20

The first column contains the intensity of the sun-pictures employed to darken the paper; the second column, the length of time which the paper was thus exposed; the third, the times, measured with the pendulum-instrument, which the diffuse light of day took to produce the same degree of shade; and lastly, the fourth column gives the same times calculated from equation (2.), in which the constant is equal to 0·12339.

As the intensity of the light in these experiments varied from 1 to nearly 50 without a greater deviation from the calculated results occurring than that which may fairly be ascribed to the unavoidable experimental errors, we conclude

> That equal products of the intensity of the light into the time of insolation correspond, within very wide limits, to equal shades of darkness produced on chloride-of-silver paper of uniform sensitiveness.

Upon this important proposition a method may be founded for measuring the chemical action of light by means of simple observations. For, if we assume as the unit of photo-chemical action that intensity of light which produces in the unit of time a given degree of shade, we have only to determine on a strip of paper, blackened in the pendulum-apparatus, the point where the shade of the strip coincides with the given unalterable tint. The reciprocals of the times which correspond to these points of equal shade give the intensity of the light expressed in terms of the above unit.

It is clear that this method is available only under the suppositions,

(I.) That the phenomena of induction, accompanying the light of the intensities employed in the measurement of the total daylight, are of so short a duration that the variations thus produced fall within the limits of the necessary experimental errors;

(II.) That it is possible to prepare a photographic surface possessing a perfectly constant degree of sensitiveness;

(III.) That an unchangeable shade of blackness is obtainable which can be easily prepared, and can be exactly compared to a photographically tinted paper.

(I.)

In order to investigate the influence of photo-chemical induction upon the blackening of the chloride-of-silver paper, we have employed the following method. By means of the pendulum-apparatus we exposed strips of the same sensitive paper quickly one after the other to the light of a cloudless sky, insolating the first strip during n_0 vibrations of the pendulum, the second strip during n_1 vibrations, and determining on each of these strips the points of equal shade. The times of insolation, t_0, t_1, t_2 . . ., corresponding to each of these points are obtained from Table I. If no appreciable induction occurs, the products n_0t_0, n_1t_1, n_2t_2, &c. must, in accordance with the former proposition, be equal. If, on the contrary, the chemical action continued for a certain length of time after each vibration, as is the case with photo-chemical induction, the products $n_0\ t_0$ must regularly alter with increasing n. The following experiments prove that this is not the case.

Experiment III.—Intensity No. 1.

n.	t.	nt.	Deviation from Mean.
4	1·024	4·096	−0·067
4	1·041	4·164	+0·001
4	1·063	4·252	+0·089
8	0·532	4·256	+0·093
8	0·525	4·200	+0·037
12	0·341	4·092	−0·071
12	0·340	4·080	−0·083

The same readings by a second observer.

n.	*t.*	*nt.*	Deviation from Mean.
4	1·048	4·192	−0·002
4	1·054	4·216	+0·026
4	1·054	4·216	+0·026
8	0·515	4·120	−0·070
8	0·520	4·160	−0·030
12	0·342	4·104	−0·086
12	0·360	4·320	+0·130

The same observations, giving the mean of seven readings.

n.	*t.*	*nt.*	Deviation from Mean.
4	1·028	4·112	−0·028
4	1·036	4·144	+0·004
4	1·036	4·144	+0·004
8	0·513	4·104	−0·036
8	0·501	4·008	−0·132
12	0·354	4·248	+0·108
12	0·352	4·224	+0·084

Intensity No. 2.

n.	*t.*	*nt.*	Deviation from Mean.
12	1·022	12·264	+0·505
12	0·982	11·784	+0·025
18	0·654	11·772	+0·013
18	0·655	11·790	+0·031
24	0·479	11·496	−0·263
24	0·477	11·448	−0·311

Intensity No. 3.

n.	*t.*	*nt.*	Deviation from Mean.
3	0·975	2·925	−0·011
3	0·975	2·925	−0·011
4	0·739	2·956	+0·020
4	0·735	2·940	+0·004
6	0·487	2·922	−0·014
6	0·492	2·952	+0·016

Intensity No. 4.

n.	*t.*	*nt.*	Deviation from Mean.
2	1·053	2·106	−0·004
2	1·057	2·114	+0·004
4	0·523	2·092	−0·018
4	0·532	2·128	+0·018

Intensity No. 5.

n.	t.	nt.	Deviation from Mean.
9	0·810	7·290	+0·074
9	0·793	7·137	−0·079
12	0·603	7·236	+0·020
12	0·600	7·200	−0·016

Intensity No. 6.

n.	t.	nt.	Deviation from Mean.
1	1·061	1·061	+0·032
1	1·050	1·050	+0·021
2	0·502	1·004	−0·025
2	0·502	1·004	−0·025

Intensity No. 7.

n.	t.	nt.	Deviation from Mean.
2	1·129	2·258	−0·008
6	0·379	2·274	+0·008

Considering the importance of this question, we deem it advisable to record another series of experiments, made for the purpose of investigating the influence of photo-chemical induction on the results of our measurements. They were made by allowing a circular disc of metal, having a sector cut out, to revolve for the same length of time, but at different rates, over two papers of the same degree of sensibility. The disc revolved at the rate of 30 revolutions per minute over one paper, and at the rate of 366 revolutions per minute over the other paper; the object being to determine whether the shade produced by the same intensity of the light and the same length of insolation remained constant, and was independent of the rate of rotation of the disk. Inasmuch as the results of these experiments, which were made on August 1, 1859, at 12^h noon, with the light of a cloudless sky, coincide with those of the former series, we do not think it necessary to enter into a full description of the experiments.

We may therefore conclude

That photo-chemical induction does not exert any prejudical effect with intensities of light such as are employed in the measurements under consideration.

(II.)

The next question upon which the successful solution of our problem materially depends, concerns the possibility of preparing a photographic paper which shall always possess the same degree of sensitiveness. In describing this portion of our investigation, we have thought it necessary to enter more minutely into the experimental details than perhaps may be consistent with the reader's patience, because we felt that, unless a complete description of the experiments were given, it would be impossible to remove the most weighty objection which can be urged against photometric measurements based upon a comparison of photographic shades.

It appeared most rational to avoid all complicated photographic receipts for the preparation of our sensitive surface, and we therefore limited our investigation to the case of a simple paper covered with a film of pure chloride of silver.

For the purpose of comparing the sensitiveness of papers prepared in various ways and under varying conditions, we employed a strip of paper which had been photographically shaded in the pendulum-photometer, and afterwards fixed in a bath of hyposulphite of soda. The strip exhibited a gradually increasing shade from its white to its dark end, and was furnished with an arbitrary scale, so that the particular shade corresponding to a given number could easily at any time be read off by the soda-flame.

In order to test whether any given papers possessed an equal degree of sensitiveness, they were exposed for equal lengths of time to the same light, and then, by means of the arrangement represented in fig. 3, they were examined to see whether they exhibited the same degree of shade; that is, whether they corresponded to the same number on the scale adapted to the fixed strip.

We always employed a solution of chemically pure crystallized nitrate of silver as the silvering liquid. The pure chloride of sodium required for obtaining a film of chloride of silver was prepared by passing gaseous hydrochloric acid into a concentrated solution of common salt, washing the precipitated chloride of sodium with water, and heating it strongly in a platinum basin.

We have made the following series of experiments for the purpose of determining the influence exerted on the sensitiveness of the paper by the concentration of the solution of salt, the quantity of silver contained in the silvering solution, the quality of paper used, and the changes of atmospheric temperature and moisture.

1. *Silvering the Paper.*

Pieces of the same perfectly homogeneous salted paper, of a quality such as is usually employed by photographers, prepared according to a method hereafter described, were allowed to lie for two minutes upon the surface of silver solutions of different strengths, as follows:—

Paper	*a*	on a solution	containing	12 $AgNO_6$	to 100	of water.
„	*b*	„	„	10	„	„
„	*c*	„	„	8	„	„
„	*d*	„	„	6	„	„

The papers were then air-dried in the dark, exposed for one and the same time to the daylight, and their shade determined. The following numbers were obtained: the readings A were made by one independent observer, the readings B by another; and each number is the mean of several readings. Equality in the numbers denotes equality in the shade, that is, equality in the sensitiveness of the paper.

Experiment IV.

Intensity No. 1.

Parts of nitrate of silver to 100 of water.	Observations.	
	A.	B.
12	128·6	129·7
10	128·7	127·0
8	128·7	128·0
6	129·7	130·0

Intensity No. 2.

Parts of nitrate of silver to 100 of water.	Observations.	
	A.	B.
12	125·5	125·0
10	125·5	125·5
8	125·4	124·2
6	161·5	160·2

Intensity No. 3.

Parts of nitrate of silver to 100 of water.	Observations.	
	A.	B.
12	110·0	110·0
10	109·5	109·3
8	109·6	109·3
6	119·0	120·0

Intensity No. 4.

Parts of nitrate of silver to 100 of water.	Observations.	
	A.	B.
12	90·6	90·0
10	88·0	88·3
8	90·7	89·4
6	89·6	89·0

From these numbers it is seen that the sensitiveness of the paper remains unaltered when the concentration of the silver solution varies from 8 to 10 or 12 parts of nitrate of silver to 100 of water, but that when a solution containing 6 parts of this salt to 100 of water is employed, the point at which alteration occurs is approached.

The influence of the concentration of the silver solution having thus been determined, it was next necessary to examine the dependence of the sensitiveness of the paper upon the length of time during which it remained upon the silver solution. For this purpose pieces of the same homogeneous salted paper were laid for various times upon the surface of a silver solution containing 12 parts of nitrate of silver to 100 of water:—

Paper *a* silvered for $\frac{1}{4}$ of a minute.
,, *b* ,, 1 minute.
,, *c* ,, 8 minutes.

On determining the shades of paper thus prepared and insolated for an equal time, the following results were obtained:—

Experiment V.

Intensity No. 1.

Duration of the silvering.	Observations.	
	A.	B.
0′ 15″	140·6	140·5
1 0	139·0	140·0
8 0	139·6	139·0

Intensity No. 2.

Duration of the silvering.	Observations.	
	A.	B.
0′ 15″	91·0	91·0
1 0	91·5	90·5
8 0	91·5	92·0

Experiment V. (*continued*).

Intensity No. 3.

Duration of the silvering.	Observations. A.
0′ 15″	45·9
1 0	47·1
8 0	45·0

Intensity No. 4.

Duration of the silvering.	Observations. A.
0′ 15″	89·9
1 0	90·0
8 0	89·2

Hence we may conclude that the time during which the paper lies on the surface of the silver-bath can vary from 15 seconds to 8 minutes without any difference in the sensitiveness of the paper being noticeable.

If the duration of the silvering be shortened below the 15 seconds, a film of chloride of silver is obtained which is much less sensitive than that obtained by a longer silvering.

It appeared to be of special importance to determine by experiment how long a silver-bath can be used without the quantity of nitrate of silver being reduced below 8 parts to 100 of water, at which point the sensitiveness of the paper may begin to alter. We found that when a paper was silvered, rather more nitrate of silver than water was removed from the silver-bath; that, however, two-thirds of a solution containing 12 of nitrate of silver to 100 of water may be used up before the quantity of silver salt sinks from 12 to 8. One square decimetre of paper does not absorb more than 0·01 grm. of nitrate of silver from a solution of the above strength.

Not only a diminution in the silver occurs on using the silver-bath, but likewise a formation of nitrate of soda takes place, which might, by its presence, affect the sensitiveness of the paper. We have therefore compared a freshly prepared silver-bath with one which had been long in use; and the results of this examination are seen in the following Tables, and show that the occurrence of the nitrate of soda produces no effect upon the sensitiveness of the paper.

Experiment VI.

Silver solution.	Intensity No. 1.		Intensity No. 2.
	A.	B.	A.
Long used	130.2	130·8	73·0
Freshly prepared ...	130·0	131·5	73·4
Freshly prepared ...	130·8	130·9	73·2
Long used	130·0	130·3	74·0

The next series of observations show the length of time which the silvered paper may be preserved in the dark before insolation without alteration of its sensitiveness. The paper employed was silvered in a solution containing 12 parts of nitrate of silver to 100 of water.

Experiment VII.

Kept in the dark for	Intensity No. 1.		Kept in the dark for	Intensity No. 2.	Kept in the dark for	Intensity No. 3.
	A.	B.		A.		A.
1 hour......	100·0	101·0	5 hours ...	99·3	5 hours ...	111·8
5 hours ...	98·9	99·0	6 hours ...	98·6	6 hours ...	109·8
9 hours ...	100·0	101·0	7 hours ...	98·8	7 hours ...	109·4
			8 hours ...	98·4	8 hours ...	109·8

Kept in the dark for	Intensity No. 4.		Kept in the dark for	Intensity No. 5.
	A.	B.		A.
4 hours ...	99·8	99·7	4 hours ...	99·2
15 hours ...	100·8	101·0	15 hours ...	100·0

2. *Salting the Paper.*

If the paper be allowed to float upon the surface of the solution of chloride of sodium as it is allowed to do upon the nitrate-of-silver solution, a paper is obtained which, after drying and silvering as already described, exhibits a sensitive surface of great irregularity, as is seen from the following experiments. In these, different parts of the same sheet of paper lying 1 decimetre from each other were examined, by two observers, A and B. The readings differ widely among themselves, a circumstance which could not occur if the sensitiveness of the film had been equal throughout the sheet.

Experiment VIII.

Part of Paper.	Intensity No. 1.		Intensity No. 2.		Intensity No. 3.		Intensity No. 4.	
	Solution containing 2 per cent. NaCl.		Solution containing 4 per cent. NaCl.		Solution containing 7 per cent. NaCl.		Solution containing 8 per cent. NaCl.	
	A.	B.	A.	B.	A.	B.	A.	B.
Upper part of sheet ...	100·0	100·0	96·3	......	114·4	115·0	94·0	93·0
Middle part of sheet ...	116·5	117·5	100·0	......	122·6	122·5	99·0	99·6
Lower part of sheet ...	......	......	122·2	......	141·0	140·8	109·6	109·6

From the above experiments it appears that the most sensitive portions of the sheet of paper were those which were lowest when the sheet was hung to dry vertically—that is, those parts by which the salt solution had been most thoroughly imbibed. We therefore endeavoured to obtain a homogeneously sensitive paper by immersing the paper in the solution of salt, and allowing it to soak for five minutes. The salt solution employed contained 4 per cent. of chloride of sodium, the silver solution contained 12 parts of nitrate of silver to 100 parts of water. The following experiments give the results obtained by this mode of treatment:—

Experiment IX.

Single Sheet of Paper.	Intensity No. 1.		Intensity No. 2.		Intensity No. 3.		Intensity No. 4.	
	A.	B.	A.	B.	A.	B.	A.	B.
Upper part..................	96·9	98·0	121·6	120·2	72·0	72 0	87·5	87·8
Middle part	97·0	95·2	121·6	120 0	72·6	72 0	87 0	87·8
Lower part..................	97·5	98·0	122·5	......	......	......	88 0	87·5

Three Sheets of Paper.	Intensity No. 1.		Intensity No. 2.	Intensity No. 3.	
	A.	B.	A.	A.	B.
No. 1. Upper part.........	83 6	83·8	69·7	87·0	86·5
No. 2. Middle part	84·2	84·0	69·7	87·3	87·8
No. 3. Lower part	85·5	85·6	69·2	88·0	88·0

These observations show that, in order to obtain a homogeneous sensitive film of chloride of silver, the paper must not be *laid upon* but *immersed in* the chloride-of-sodium solution.

From the following experiments we learn the influence which the concentration of the salt solution exerts upon the sensitiveness of the paper. The papers salted in different solutions were all silvered in a bath containing 12 parts of nitrate of silver to 100 parts of water.

Experiment X.

Intensity No. 1.			Intensity No. 2.			Intensity No. 3.		
Na Cl to 100 of water.	A.	B.	Na Cl to 100 of water.	A.	B.	Na Cl to 100 of water.	A.	B.
1	62·6	60·4	4	93·2	93 0	6	67·6	68·6
2	95·7	94·7	5	92·9	93·3	8	83·4	83·7
3	132 6	129·6	6	111·5	113·2	10	94·7	93·7
4	167·0	168·0				12	97·0	95·0

Intensity No. 4.		Intensity No. 5.		
Na Cl to 100 of water.	A.	Na Cl to 100 of water.	A.	B.
13	154·5	12	69·0	70·0
14·5	159·6	15	75·0	78·5
16	161·6	18	95·0	95·0
		21	94·5	95·0

An examination of the above Table shows

That the sensitiveness of the paper increases rapidly with increasing strength of the chloride-of-sodium solution, and that, as far as the observations extend, no limit exists beyond which an increase or a diminution of the percentage of salt in solution ceases to affect the sensitiveness of the film.

In order to obtain constant results, it is therefore necessary to employ a solution of chloride of sodium of unvarying strength. We have decided upon using a solution which contains 3 per cent. of chloride of sodium. Such a solution is especially convenient, because the paper dipped into it removes salt and water almost exactly in the proportions in which they are contained in solution; thus 225 cubic centimetres of a 3 per cent. salt-bath was altered from 2·948 per cent. NaCl to 2·935 per cent. by impregnating 0·72 square metre of paper. In another experiment the strength of 10 litres of salt solution containing 2·97 per cent. NaCl, was only increased to 3·08 per cent. by impregnating $4\frac{1}{2}$ square metres of paper. It is therefore possible to impregnate 5 square metres of paper with a solution containing 60 grammes of chloride of sodium, without any danger of reducing the strength of the salt solution below the point at which differences begin to appear.

3. *Influence of the description of Paper employed.*

In the examination of the effect of change of quality in the paper used, we have confined our experiments to three kinds of paper, differing extremely in thickness, from the thickest to the thinnest commonly in use among photographers.

One square decimetre of the first of these, called paper *a*, weighed 0·354 grm.; the same area of the second, called *b*, weighed 0·732 grm.; and the same quantity of the third sort, called *c*, weighed 0·876 grm. From the first series of experiments made with these papers, we thought that the varying thickness of the paper was of the greatest moment in determining the sensibility of the film; thus, for instance, the three sorts of papers, sensitized in exactly the same way, gave the following unequal readings:—

Papers.	Intensity No. 1.
a	90·0
b	75·3
c	72·5

We soon convinced ourselves, however, that this want of agreement was not caused by any difference in the sensitiveness of the film, but solely by the difference in the partial opacity of the papers. If the transparency was got rid of by placing a piece of thick white paper behind the tinted papers whilst reading off, the following numbers were obtained instead of the foregoing:—

Papers.	Intensity No. I.
a	73·6
b	73·6
c	72·0

The following series of readings show still more clearly that no difference in the shade of these papers can be observed when a white background is placed behind the tinted papers:—

Experiment XI.

Paper.	Na Cl to 100 of water.	Ag N O^6 to 100 of water.	Intensity No. 1.		Intensity No. 2.
			A.	B.	
a	2	12	73·0	71·0	109·5
b	2	12	73·0	73·0	112·0
c	2	12	69·5	73·6	109·5

Paper.	Na Cl to 100 of water.	Ag N O^6 to 100 of water.	Intensity No. 1.	Intensity No. 2.	Intensity No. 3.
a	16	12	89·3	120·0	142·4
b	16	8	91·0	120·0	142·9
c	16	10	90·0	120·0	141·9

Hence we may conclude

That variation in the thickness of white paper, such as is usually employed for photographic purposes, is without influence upon the sensitiveness of the film of chloride of silver.

4. *Influence of the Changes of Atmospheric Temperature and Moisture.*

In order to become acquainted with the influence exerted by change of temperature and moisture upon the sensitiveness of the paper, we gummed portions of the same sheet of sensitized air-dried paper upon two tin boxes, filled with water of different temperatures, and exposed these two papers for the same length of time to the same intensity of light. No greater differences in shade were observed in the papers thus tinted than such as arose from the unavoidable experimental errors; this is seen from the following numbers:—

Experiment XII.

Intensity No. 1.								Intensity No. 2.			
Temperature.								Temperature.			
+3° C.		+50° C.		+3° C.		+50° C.		+4° C.		+30° C.	
A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
89·2	88·3	88·0	89·0	88·2	88·5	88·0	88·5	81·6	80·6	81·6	80·6

Hence there can be no doubt

That the ordinary changes of atmospheric temperature and moisture do not affect the sensitiveness of the paper.

From the results of the foregoing series of experiments it is easy to select the conditions under which a paper of constant sensibility can be obtained.

Preparation of the Standard Paper.

We give the following receipt for preparing a constant standard paper, by help of which comparative measurements can be carried out at any time or at any place:—

300 grammes of pure chloride of sodium are dissolved in 10 litres of water, and the solution poured into a shallow zinc vessel large enough to float the paper. The sheets of paper, about 0·3 metre in area, are one by one laid flat in the solution, and the vessel slightly agitated in order to remove adhering bubbles of air. When the sheet has been immersed for 5 minutes, it is taken out of the solution and dried by hanging in the air in a vertical position. The solution thus prepared will serve to salt seventy sheets of paper, each having an area of 0·3 metre. This salted paper can be preserved for months without being in any way injured.

The silvering is managed, with the precautions ordinarily in use amongst photographers, by placing the paper, after each sheet has been cut into four pieces, upon the surface of a solution containing 120 grammes of nitrate of silver to 1 litre of water, placed in a flat glass dish. Each piece of paper is allowed to lie upon the surface of the silver-bath for 2 minutes. This litre of silver solution serves to sensitize 500 such pieces of paper, after which its volume will be reduced to one-half. The standard paper thus prepared can be preserved in the dark after drying in the air for from 15 to 24 hours without undergoing any appreciable change in its sensitiveness.

It is scarcely necessary to add that, by adhering to the proportions here given, smaller quantities of the standard paper may likewise be prepared.

We next give a series of experiments to show that such a standard paper, prepared at different times and under various conditions, can always be obtained homogeneous throughout its surface, and of a perfectly constant sensitiveness.

Experiment XIII.

Size of paper 0·3 square metre.	Intensity No. 1.		Intensity No. 2.	
	A.	B.	A.	B.
Upper part	115·0	115·0	129·4	126·6
Middle part	115·4	116·4	129·0	127·2
Lower part	116·0	115·4	129·5	128·0

The standard paper used for the above experiment consisted of a sheet 0·3 of a square metre in size; and the portions which were selected for trial lay at a distance of about 25 centimetres from each other. In order to show that no irregularities occurred in a large number of sheets prepared in the same salt solution, we add a comparison of the sensitiveness of eighteen sheets of standard paper, each of an area of 0·075 square metre, salted in a solution containing 2·95 per cent. of chloride of sodium.

Paper.	Intensity No. 1.		Paper.	Intensity No. 2.	
	A.	B.		A.	B.
Middle part of Sheet No. 1 ...	98·0	98·3	Upper part of Sheet No. 1 ...	88·0	88·0
Middle part of Sheet No. 9 ...	98·3	98·9	Middle part of Sheet No. 8 ...	89·5	89·6
Middle part of Sheet No. 18...	98·0	99·0	Lower part of Sheet No. 17 ...	89·5	89·5

Paper.	Intensity No. 3.		Paper.	Intensity No. 4.	
	A.	B.		A.	B.
Upper part of Sheet No. 2 ...	69·0	69·5	Lower part of Sheet No. 4 ...	70·5	70·0
Middle part of Sheet No. 4 ...	69·5	70·8	Lower part of Sheet No. 12 ...	70·2	70·0
Middle part of Sheet No. 11...	69·3	70·0	Upper part of Sheet No. 16 ...	70·0	71·0
			Upper part of Sheet No. 18 ...	70·5	70·5

Paper.	Intensity No. 5.		Paper.	Intensity No. 6.	
	A.	B.		A.	B.
Upper part of Sheet No. 4 ...	99·5	99·9	Lower part of Sheet No. 8 ...	63·9	62·5
Middle part of Sheet No. 6 ...	100·5	100·0	Middle part of Sheet No. 16...	62·5	62·5
Lower part of Sheet No. 9 ...	101·0	101·0	Upper part of Sheet No. 17 ...	61·8	61·5

The following Tables contain the results obtained from three salt solutions of the same approximate strength but prepared at different times, the exact composition of each being determined by silver analysis. In these solutions three sheets of paper, each 0·075 sq. metre in area, were prepared, the sheets being afterwards sensitized as described. Here, likewise, the same uniformity is strikingly seen.

Paper.	Na Cl to 100 parts of water.	Intensity No. 1.	Intensity No. 2.
Upper part of Sheet No. 2 ...	3·026	87·0	75·4
Middle part of Sheet No. 3 ...	2·950	86·3	74·4
Middle part of Sheet No. 2 ...	3·028	86·0	74·9
Lower part of Sheet No. 2 ...	3·000	85·9	74·4

Paper.	Na Cl to 100 parts of water.	Intensity No. 1.		Intensity No. 2.	
		A.	B.	A.	B.
Upper part of Sheet No. 2 ...	2·950	77·5	76·5	89·0	87·0
Middle part of Sheet No. 1 ...	3·026	77·0	77·5	89·0	88·0
Middle part of Sheet No. 3 ...	3·000	78·2	78·0	90·1	93·0
Lower part of Sheet No. 2 ...	3·026	78·9	78·5	89·9	90·9

Paper.	Na Cl to 100 parts of water.	Intensity No. 1.
Upper part of Sheet No. 3 ...	2·950	86·2
Middle part of Sheet No. 3 ...	3·028	87·0
Middle part of Sheet No. 2 ...	3·000	86·8
Lower part of Sheet No. 2 ...	3·028	87·5

Paper.	Na Cl to 100 parts of water.	Intensity No. 1.		Intensity No. 2.	
		A.	B.	A.	B.
Upper part of Sheet No. 2 ...	2·950	70·2	70·0	101·3	101·5
Lower part of Sheet No. 2 ...	3·026	70·6	69·3	101·5	101·7
Middle part of Sheet No. 1 ...	3·026	70·0	69·5	100·9	100·9
Middle part of Sheet No. 3 ...	3·000	70·0	70·4	101·0	100·0

We may, therefore, conclude that the standard photographic paper prepared according to the above receipt possesses a degree of sensitiveness sufficiently constant for all the purposes of our measurements.

(III.)

For the purpose of obtaining a unit of measurement, we need a perfectly fixed and unalterable shade of colour, which can be at any time easily prepared; this is made by mixing oxide of zinc and lamp-black in certain proportions, and grinding them together until no change of tint is produced by further rubbing. The oxide of zinc is prepared in the wet way chemically pure, and then ignited at a low red heat for 5 minutes in a closed platinum crucible. The lamp-black is prepared chemically pure by allowing a turpentine lamp to burn under a large porcelain dish filled with cold water, and igniting the soot, which is deposited on the outside of the dish, for 5 minutes in a covered platinum crucible. In this way a fine impalpable powder is obtained which burns without leaving the slightest trace of ash.

Experiment showed that the tint obtained by mixing 1 part of the lamp-black with 1000 parts of oxide of zinc is that about which the eye can distinguish between very slight alterations of shade, but that these slight alterations cannot be observed when the tint is either darker or lighter. Hence we have adopted the mixture containing 1000 parts of oxide of zinc to 1 part of lamp-black as the standard tint. In order that the colour may adhere to the paper, it is mixed with water containing 1 per cent. of isinglass. During the preparation of the colour it was noticed that the shade of the mixture became gradually darker when it was well ground on a glass plate and afterwards dried, but that after a time a point was reached at which no alteration in shade was produced by repeating the operations of grinding and drying. The following observations of points of equal shade made upon a fixed strip illustrate this gradual change.

	First Preparation.		
	A.	B.	Mean.
After the first grinding	66·0	66·2	66·1
After the second grinding ...	72·9	72·5	72·7
After the third grinding......	72·4	72·6	72·5
After the fourth grinding ...	72·8	73·0	72·9

In order to obtain a perfectly constant colour, the mixture must be well ground on a glass plate with water for an hour, then dried in the water-bath, and this operation repeated until no difference in shade can be detected between the mixture in various stages on examination in the usual manner upon a fixed strip.

Four separate mixtures, made at different times and with differently prepared constituents, gave the observations contained in the following Table, in which the constant nature of the tint produced is seen.

	1st Reading.		2nd Reading.		Mean.
	A.	B.	A.	B.	
1. First preparation	72·0	71·8	71·5	72·5	71·95
2. Second preparation ...	72·5	72·0	72·0	72·0	72·12
3. Third preparation ...	72·9	73·0	......	......	72·95
4. Fourth preparation ...	72·0	72·0	72·2	73·2	72·35

We may therefore consider it proved

That the colour used as the measure of the standard tint can at any time be prepared of a constant and unalterable shade.

Having, in the foregoing, described the mode in which a standard photographic paper of constant sensitiveness, and a standard tint of unvarying shade can be prepared, we need only apply the proposition that equal products of the intensities into the times of insolation produce equal shades of blackness, in order to found a method of measurement and comparison of the chemical action of the total daylight. As the *unit of measurement*, we propose to adopt

That intensity of the light which in one second of time produces the standard tint of blackness upon the standard paper.

When the standard paper is insolated in the pendulum-apparatus, a strip is obtained which is tinted with every gradation of shade from dark to white. If the point on this strip which coincides in shade with a piece of paper covered with the standard tint be determined by means of the arrangement (fig. 3), we have only to look for the corresponding reading of the millimetre scale in Table I. to obtain the time of insolation t in seconds which was necessary in order to produce this shade. If this time of insolation were found to be one second, the intensity of the light then acting would, according to definition, be $I=1$. For any other time of insolation, t for example, the intensity of the chemical rays would be $\frac{1}{t}$. The following Table (II.) gives in column II. the intensities, for one vibration of the pendulum, corresponding to the points of equal shade of the standard paper and standard tint, as read off on the millimetre scale in column I. The intensities corresponding to n vibrations of the pendulum are obtained by dividing the numbers in column II. by n.

Table II.

I. Millims.	II. Intensity.	I. Millims.	II. Intensity.	I. Millims.	II. Intensity.	I. Millims.	II. Intensity.	I. Millims.	II. Intensity.	I. Millims.	II. Intensity.
0	0·834	32	0·997	64	1·183	96	1·429	128	1·824	160	2·710
1	0·839	33	1·002	65	1·190	97	1·439	129	1·840	161	2·763
2	0·844	34	1·007	66	1·197	98	1·448	130	1·856	162	2·816
3	0·849	35	1·012	67	1·203	99	1·458	131	1·874	163	2·869
4	0·853	36	1·018	68	1·209	100	1·467	132	1·892	164	2·923
5	0·858	37	1·023	69	1·215	101	1·477	133	1·911	165	2·977
6	0·864	38	1·029	70	1·221	102	1·487	134	1·930	166	3·048
7	0·869	39	1·034	71	1·228	103	1·497	135	1·949	167	3·119
8	0·874	40	1·040	72	1·235	104	1·507	136	1·969	168	3·190
9	0·879	41	1·046	73	1·242	105	1·517	137	1·990	169	3·262
10	0·884	42	1·051	74	1·249	106	1·528	138	2·011	170	3·334
11	0·889	43	1·0[illegible]7	75	1·256	107	1·539	139	2·032	171	3·437
12	0·894	44	1·062	76	1·263	108	1·551	140	2·053	172	3·534
13	0·899	45	1·068	77	1·270	109	1·563	141	2·078	173	3·650
14	0·904	46	1·074	78	1·277	110	1·575	142	2·103	174	3·759
15	0·909	47	1·079	79	1·285	111	1·586	143	2·128	175	3·891
16	0·914	48	1·085	80	1·293	112	1·598	144	2·153	176	4·016
17	0·919	49	1·090	81	1·301	113	1·610	145	2·179	177	4·167
18	0·924	50	1·096	82	1·309	114	1·622	146	2·207	178	4·367
19	0·929	51	1·102	83	1·317	115	1·634	147	2·235	179	4·566
20	0·935	52	1·108	84	1·325	116	1·647	148	2·263	180	4·807
21	0·940	53	1·114	85	1·333	117	1·660	149	2·291	181	5·051
22	0·945	54	1·120	86	1·342	118	1·673	150	2·320	182	5·348
23	0·950	55	1·127	87	1·350	119	1·686	151	2·354	183	5·682
24	0·955	56	1·133	88	1·359	120	1·700	152	2·389	184	6·212
25	0·961	57	1 139	89	1·367	121	1·715	153	2·424	185	6·848
26	0·966	58	1·145	90	1·376	122	1·730	154	2·459	186	7·633
27	0·971	59	1·151	91	1·385	123	1·745	155	2·494	187	8·620
28	0·976	60	1·156	92	1·394	124	1·760	156	2·537		
29	0·981	61	1·163	93	1·402	125	1·776	157	2·580		
30	0·986	62	1·170	94	1·411	126	1·792	158	2·623		
31	0·992	63	1·176	95	1·420	127	1·808	159	2·666		

The observations are carried out in the manner fully described in the commencement of the present communication. In order to make several observations quickly after each other, the screw (k, fig. 1) is loosened, and, after each observation, the slide (G) drawn out rather more than the width of the slit. The readings are also made in the way described, with the arrangement fig. 3, half the hole in the block (fig. 4) being occupied with paper covered with a thick layer of the standard tint. Care must be taken that the white background upon which the strip is placed is free from spots or dirt, which by appearing through the paper may alter the readings. The paper on which the standard tint is painted must not be too thin, and must be thoroughly air-dried before use. Each comparison of shade is made five or six separate times, the scale being covered up during every reading, and the mean of these observations recorded.

As an example of such measurements, we append several observations representing the chemical action exerted upon a horizontal surface by the whole sunlight and diffuse daylight during the various hours of the day. These observations, which are contained in Table III., were carried on in Manchester, on the roof of the Laboratory of Owens College, and were made on days in which the sun sometimes shone, and sometimes was obscured by clouds. The observations are represented by the curves (fig. 5), and the maxima and minima correspond exactly with the appearance and disappearance of the sun. From these few observations an idea may be formed of the vast differences exhibited by the chemical activity of sun- and day-light about the periods of the longest and the shortest days.

Table III.

Wednesday, December 18, 1861.				Thursday, December 19, 1861.				Wednesday, July 30, 1862.			
t.	*i.*	*n.*	$\frac{i}{n}$=I.	*t.*	*i.*	*n.*	$\frac{i}{n}$=I.	*t.*	*i.*	*n.*	$\frac{i}{n}$=I.
h m				h m				h m			
10 6 A.M.	1·05	124	0·00847	9 39 A.M.	1·79	120	0·0149	7 0 A.M.	0·88	60	0·0147
10 16	2·49	170	0·0147	9 49	2·10	150	0·0140	7 20	0·85	32	0·0266
10 26	1·60	100	0·0160	10 1	1·89	120	0·0157	7 35	1·07	25	0·0428
10 36	1·49	90	0·0166	10 21	1·93	100	0·0193	7 50	0·89	16	0·0556
10 47	1·47	100	0·0147	10 31	1·72	80	0·0215	8 0	0·83	10	0·0830
10 56	1·34	80	0·0168	10 41	2·05	80	0·0256	8 35	0·92	12	0·0767
11 6	1·47	80	0·0184	10 51	1·66	80	0·0208	9 0	1·33	15	0·0887
11 16	1·59	100	0·0159	11 1	1·93	90	0·0215	9 5	1·20	10	0·120
11 26	1·41	80	0·0176	11 11	1·91	80	0·0239	9 30	1·22	7	0·174
11 36	1·39	75	0·0185	11 21	1·91	80	0·0239	10 10	1·12	5	0·224
11 46	1·25	80	0·0156	11 31	1·91	80	0·0239	10 20	0·91	5	0·182
11 56 A.M.	1·46	66	0·0221	11 41	1·73	80	0·0216	10 30	0·83	10	0·0830
12 6 P.M.	1·52	60	0·0253	11 51 A.M.	1·69	61	0·0277	11 0	0·86	11	0·0782
12 16	1·42	50	0 0284	12 1 P.M.	1·66	60	0·0277	11 30	0·86	4	0·215
12 26	1·42	45	0·0316	12 11	1·54	50	0·0308	12 0	0·86	3	0·287
12 36	1 20	40	0·0300	12 21	1·49	50	0·0298	12 30 P.M.	0·86	3	0·287
12 46	0·92	80	0·0115	12 41	1·10	50	0·0519	1 30	0·88	6	0·147
12 57	1·02	120	0·0085	12 51	1·37	65	0·0211	2 0	1·11	8	0·139
1 6	1·19	90	0·0132	1 1	1·02	50	0·0204	2 30	1·33	13	0·110
1 16	1·38	75	0·0184	1 11	1·12	65	0·0172	3 0	1·22	9	0·136
1 26	1·22	65	0·0188	1 21	1·56	90	0·0173	4 0	1·27	15	0·0846
1 36	1·05	50	0·0210	1 36	1·69	86	0·0197	4 35	1·22	18	0·0678
1 47	0·84	60	0·0140	1 46	1·75	100	0·0175	5 0	1·49	20	0·0745
1 56	1·26	100	0·0126	1 56	1·54	100	0·0154	5 30	1·34	25	0·0536
2 10	1·36	150	0·00906	2 6	1·22	100	0·0122	6 0	1·24	40	0·0310
2 22	1·34	150	0·00893	2 16	1·40	120	0·0117				
2 32	1·41	160	0·00881	2 27	1·59	160	0·00994				
2 42	1·55	200	0·00775	2 45	1·50	180	0·00833				
2 52	1·36	225	0·00529	2 53	1·25	160	0·00781				
3 5	1·56	400	0·00390	3 8	1·45	250	0·00580				
3 25 P.M.	1·53	450	0·00340	3 21 P.M.	1·72	500	0·00344				

At the close of this communication we may remark that, by help of the pendulum-apparatus described, we have constructed a portable instrument by which a large number of measurements can be made on a few square inches of paper. We reserve the description of this instrument for a future occasion.

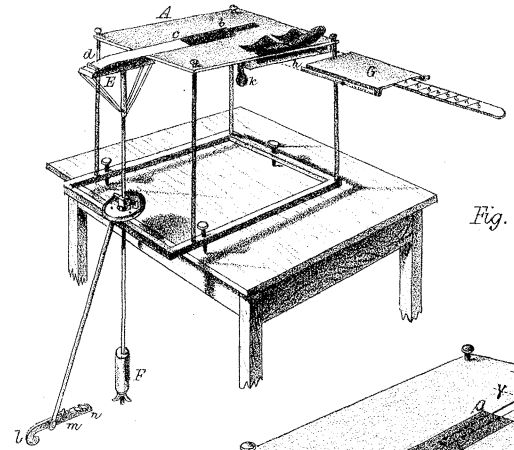

Fig. 1.

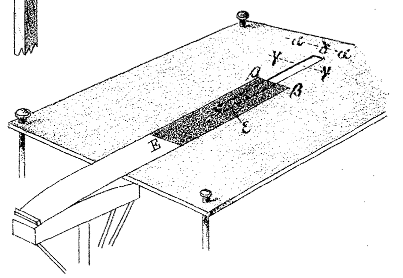

Fig. 2.

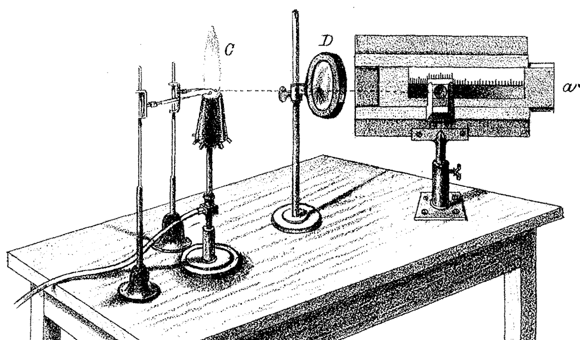

Fig. 3.

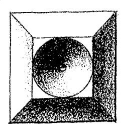

Fig. 4.

Fig. 5.