The values found for the flint-glass rod experimented on were, in grammes' weight per square centimetre,

$$M=614,330,000,$$
$$n=244,170,000,$$
$$k=423,010,000,$$
$$\sigma=\cdot 258.$$

The mode of experimenting is somewhat similar to that by which Kirchhoff investigated the value of σ for steel and brass; but there are several points of difference, especially this—that the portion of the glass rod, whose flexure and torsion are measured, is sufficiently distant from the places where external forces are applied, to eliminate the local irregularities produced by their application.

II. "Note on the relative Chemical Intensities of direct Sunlight and diffuse Daylight at different altitudes of the Sun." By HENRY E. ROSCOE, F.R.S., and JOSEPH BAXENDELL, F.R.A.S. Received February 8, 1866.

The method of determining the chemical intensity of daylight described by one of us* presents a convenient means of experimentally comparing the intensity of the chemically active rays which reach the earth's horizontal surface directly from the sun with that of the same rays reflected from the atmosphere and constituting diffuse daylight. For this purpose it is only necessary alternately to expose pieces of the standard sensitive paper, according to the method described in the memoir above mentioned, to the action of the total light of day, and to the diffuse daylight alone, which is easily done by cutting off the sun's direct rays from the sensitive paper, by throwing upon the paper a shadow cast by a small screen, having an apparent diameter slightly greater than that of the solar disk. In the first case the chemical intensity of the total daylight, in the second that of the diffuse light is determined; the difference between these two observations giving the chemical intensity of the direct sunlight. As the experiments which we have already made in this direction have led us to conclusions differing altogether from those derived from theoretical considerations concerning the relative chemical intensities of direct and diffuse sunlight, we think that, although this investigation is incomplete, the results are worthy of the attention of the Society. No direct photometrical determinations of the relative intensity of sun and diffuse light have up to this time been made; but Clausius † has calculated this relation for varying altitudes of the sun, founding his calculations upon the hypothesis (generally adopted by meteorologists to explain the red tints of the morning and evening sky) that the diffused light is reflected, not from the par-

* Bakerian Lecture, 1865. Phil. Trans. 1865, p. 605.
† Poggendorff's 'Annalen,' Bd. lxxii. p. 294.

ticles of air or solid floating material, but from the minute vesicles of water which are supposed to be always contained in large quantities in the atmosphere. According to this hypothesis, Clausius obtained the following numbers as expressing the intensities of direct sunlight and diffused daylight for altitudes varying from 20° to 60°:—

Sun's Altitudes.	Calculated Intensities of Total Daylight.	Diffuse Light.	Direct Sunlight.
20°	0·10049	0·06736	0·03313
25°	0·17808	0·09291	0·08517
30°	0·25933	0·11184	0·14749
35°	0·34049	0·12654	0·21395
40°	0·41957	0·13832	0·28125
50°	0·56686	0·15599	0·41087
60°	0·69442	0·16822	0·52620

(The intensity of sunlight at an altitude of 90°, unweakened by atmospheric absorption, is taken as the unit.)

The measurement of the relative chemical intensities were made at three localities: (1) Owens College, Manchester, 53° 29′ N., and $0^h\ 9^m\ 0^s$ W.; (2) the Observatory, Cheetham Hill, near Manchester; and (3) the summit of the Königstuhl, near Heidelberg, 1900 feet above the sea, in 49° 24′ N., and $34^m\ 48''$ E. We are indebted for the latter observations to Dr. Wolkoff, who kindly forwarded us his results through Professor Bunsen.

The following experimental numbers, obtained at Owens College, may serve to illustrate the method adopted; in most cases several (four or five) observations of the intensities of the total and diffuse light were made quickly one after the other, and the mean of all the readings taken.

Table I.—Observations at Owens College, Manchester, 53° 29′ N. $0^h\ 9^m\ 0^s$ W.

Date.	Greenwich Mean Time of Observation.	Sun's Hour Angle.	Sun's Altitude.	Intensity of total Daylight.	Number of Observations.	Intensity of diffused Light.	Number of Observations.	Intensity of direct Sunlight.
1865.	h m	° ′	° ′					
Oct. 6.	12 0	0 44 W.	31 17	·073	3	·068	4	·005
7.	9 30	36 42 E.	23 23	·060	1	·056	1	·004
	12 0	0 48 W.	30 54	·063	1	·057	1	·006
18.	11 25	7 18 E.	26 30	·075	2	·056	2	·001
	11 45	2 17 E.	26 46	·111	2	·089	2	·022
	12 30	8 58 W.	26 20	·088	4	·087	4	·001
	1 19	21 13 W.	24 15	·071	4	·067	5	·004
	2 45	42 43 W.	17 8	·062	2	·053	2	·009
24.	0 45	12 51 W.	23 42	·139	3	·113	5	·026
	1 20	21 41 W.	22 4	·123	5	·115	4	·008
Nov. 15	12 0	1 33 W.	17 55	·101	5	·082	4	·019
	12 40	11 33 W.	17 15	·065	4	·063	5	·002
	1 15	20 18 W.	15 50	·063	4	·058	5	·005
21.	12 10	3 43 W.	16 27	·056	5	·055	4	·001
	12 30	8 43 W.	16 8	·066	4	·058	5	·008
	12 45	12 28 W.	15 44	·058	4	·050	5	·008

As the altitudes here observed vary only from 15° 44′ to 31° 47′, we thought it best to collect the results into two groups, containing the eight highest and eight lowest observed altitudes.

TABLE II.—Results of Observations at Owens College.

	Number of Observations.		Mean Altitude. of Sun.	Intensity of Sky or diffused Daylight.	Intensity of direct Sunlight.	Ratio of Sun to Sky.
	Sky.	Sun.				
Group 1	33	34	17° 8′	·066	·007	0·106
2	20	24	26 38	·074	·008	0·108

The determinations made at Cheetham Hill (53° 30′ 50″ N., and 0^h 8^m 56^s W.) were sixty-three in number, in which the altitude varies from 16° 8′ to 46° 14′, and these are divided into three groups, as follows:—

TABLE III.—Results of Observations at Cheetham Hill.

	Number of Observations.		Mean Altitude of Sun.	Intensity of Sky or diffused Daylight	Intensity of direct Sunlight.	Ratio of Sun to Sky.
	Sky.	Sun.				
Group 1	23	24	19° 30′	·064	·012	0·187
2	22	22	25 31	·091	·019	0·208
3	18	17	34 8	·104	·026	0·250

The range of altitude in the Heidelberg experiments being a much wider one (viz. from 0° to 63° 49′), we have been able to arrange these (containing ninety-nine observations) in five groups, as follows:—

TABLE IV.—Results of Observations at Heidelberg.

	Number of Observations.	Range of Altitude of of Sun.	Mean Altitude of Sun.	Intensity of Sky or diffused Daylight.	Intensity of direct Sunlight.	Ratio of Sun to Sky.
Group 1	10	0° to 15°	7° 15′	·048	·002	0·041
2	19	15 — 30	24 43	·134	·066	0·472
3	31	30 — 45	34 34	·170	·136	0·800
4	22	45 — 60	53 37	·174	·263	1·511
5	17	above 60	62 30	·199	·319	1·603

The curves on Pl. I. fig. 1 are derived from the foregoing numbers, the ordinates representing the intensities and the abscissæ denoting the corresponding altitudes. The curves marked *a*, *b*, *c* give respectively the observations at Heidelberg, Cheetham Hill, and Owens College; the dotted curves represent the intensities of the diffuse light, the black curves those of the direct sunlight. The ratio of the sun and skylight for the same places is represented by the curves *a*, *b*, and *c*, fig. 2.

In the following Table the experimental ratios are compared with those calculated by Clausius.

TABLE V.—Ratio of Chemical Intensities of direct Sunlight to diffuse Light.

Sun's Altitude.	Calculated (Clausius).	Experiments.		
		Heidelberg.	Cheetham Hill.	Owens College.
20°	0·491	0·350	0·19	0·10
25	0·896	0·480	0·20	0·11
30	1·320	0·650	0·23	
35	1·690	0·820	0·26	
40	2·032	1·00	—	
50	2·634	1·37	—	
60	3·129	1·60	—	

These numbers show that whilst at 20° of altitude, according to theory, the relation of the intensities of diffuse light to direct sunlight is as 100 to 49·1, the experiments at Heidelberg give a relation of 100 to 35; those at Cheetham Hill 100 to 19, and those in Manchester 100 to 10. If we compare the theoretical ratio for higher altitudes, we find that in our latitudes the ratio even at 35° of altitude is only as 100 for diffuse light to 26 for sunlight, whereas theory gives the relation as 100 to 169. The Heidelberg observations show indeed a more rapid rise in the intensity of the direct sun's rays, the ratio reaching 100 to 82 for 35° of altitude. The great difference between these and the other experimental results must doubtless be ascribed to the considerable elevation (1900 feet above the sea) at which these observations were made.

Even at Heidelberg, however, no less than eight observations show that at low elevations the chemical action of the sun becomes altogether inappreciable, whilst that of the diffuse light is still considerable; and the same inactive condition of direct sunlight at low altitudes has been frequently observed both at Owens College and Cheetham Hill. In these cases the intensity of the sun's direct visual rays was considerable, and a strong shadow was cast; but the more highly refrangible rays were altogether absent, and the ratio became infinite.

Heidelberg Observations.

Altitude.	Direct Sun.	Diffuse Light.
0° 34′	0·000	0·026
1 32	0·000	0·024
2 29	0·000	0·038
3 27	0·000	0·028
6 0	0·000	0·030
10 40	0·000	0·083
11 51	0·000	0·079
12 58	0·000	0·080

In some of the experiments made at Cheetham Hill the shadow of a small disk was thrown on a horizontal surface of white paper, and careful estimations made of the relative brightness of the shaded and unshaded portions of the surface. A comparison of these results with those obtained at the same time for the chemical rays showed that with the sun at a mean

altitude of 25° 16′, the mean ratio of the chemical intensities of direct and diffused light being 0·23, that of the luminous intensities was 4·00, or that the action of the atmosphere was 17·4 times greater on the chemically active than on the luminous rays of sunlight. A series of photometrical experiments made afterwards at Owens College gave the following results:—

Mean altitude of the sun	12° 3′
Mean ratio of chemical intensity....	0·053
Mean ratio of luminous intensity....	1·400

It appears therefore that with the sun at an altitude of 12° 3′, the action of the atmosphere was 26·4 greater on the chemical than on the luminous rays.

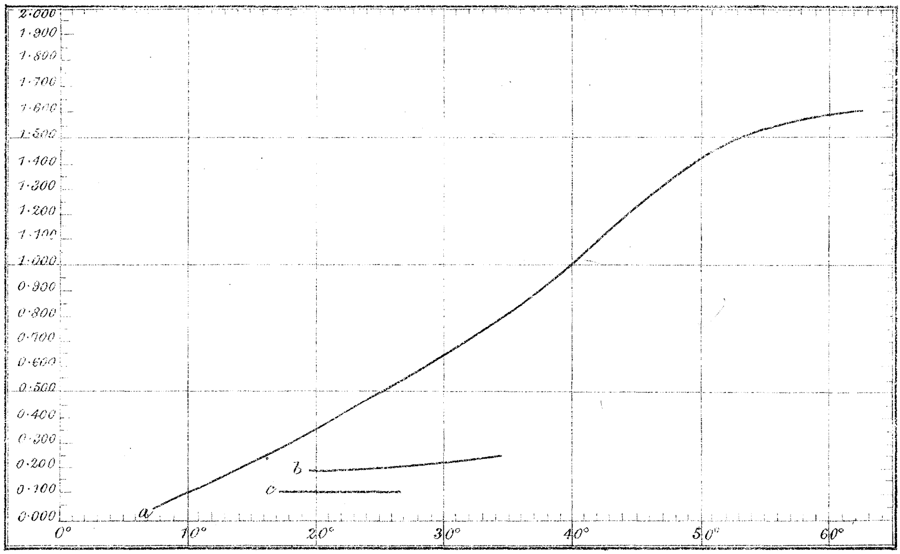
The foregoing experiments appear to prove—

I. That the effect of the atmosphere upon the highly refrangible and chemically active solar rays is regulated by totally different laws from those founded upon the hypothesis of the reflexion by means of hollow vesicles of water.

II. That the ratio of the chemical intensity of direct to diffuse sunlight for a given altitude of the sun at different localities is not constant, varying with the transparency, &c., of the atmosphere.

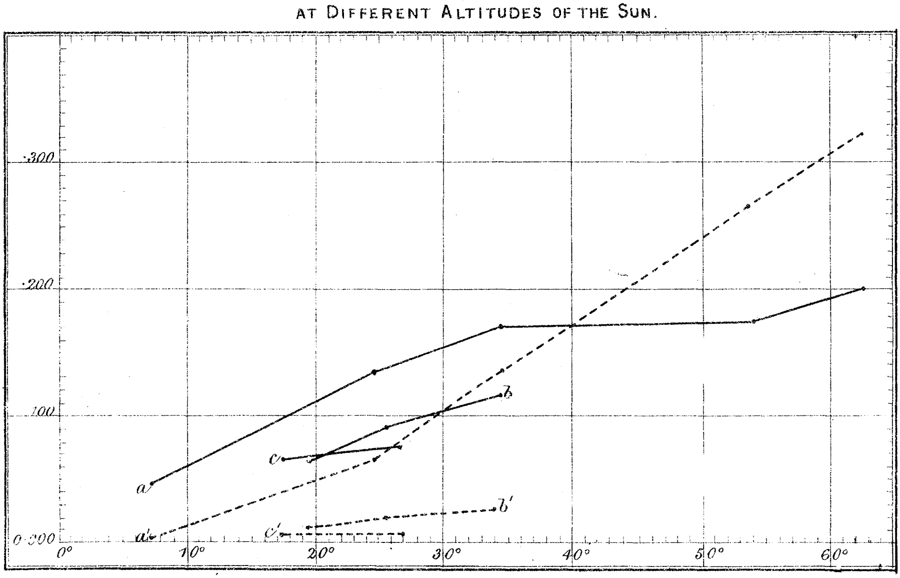
III. That this ratio of "chemical" intensity does not in the least correspond to the ratio of "visible" intensity as estimated by the eye; the action of the atmosphere being 17·4 times greater upon the chemical than on the luminous rays when the sun's altitude is about 25° 16′, and 26·4 times greater when the sun's altitude is 12° 3′.

Ratio of Direct to Diffused Light at Different Altitudes of the Sun.



a Heidelberg.
b Cheetham Hill.
c Owens' College.

Chemical Intensity of Diffused and Direct Sun-Light at Different Altitudes of the Sun.



a Heidelberg Sky, from 99 observations.
a' ——— Sun, —— 99 ———
b Cheetham Hill Sky 63
b' Cheetham Hill Sun, from 63 observations.
c Owens' College Sky, —— 58 ———
Sun 54