ON THE DEVIATIONS FROM THE LAW OF RECIPROCITY FOR BROMIDE OF SILVER GELATINE.[1]

By K. SCHWARZSCHILD.

THE so-called law of reciprocity states that sources of light of different intensity I produce an equal degree of blackening in their photographic images under different exposures t if the product $I \times t$ has the same value in the different cases. Laboratory experiments by Abney, Miethe, and Michalke have demonstrated that there are deviations from the law of reciprocity. These, however, reveal themselves most clearly in astrophotographic work. Scheiner, in 1891, proved that the increase in the number of fainter stars on prolonging the exposure fell far below what would be expected according to the law of reciprocity. In determinations of stellar brightness by the photographic method I have recently been able to confirm once more the existence of such deviations, and to follow them up in a quantitive way, and to express them in the following rule, which should replace the law of reciprocity: Sources of light of different intensity I cause the same degree of blackening under different exposures t if the products $I \times t^{0.86}$ are equal. In these experiments Schleussner's gelatine emulsion plates were employed. The exposures ranged from 3 to 5000 seconds, the intensity from one to a thousandfold, the blackening from the slightest degree up to almost complete opacity.

The results of a research by A. Schellen[2] are contradictory to the above result, as he found the law of reciprocity exactly confirmed for these same Schleussner plates, although this was after he had brought them to the maximum of a preliminary exposure. The contradiction cannot be explained, however, by the absence of a preliminary exposure in my experiments, as I

[1] *Photographische Correspondenz*, 1899.

[2] "Ueber die Giltigkeit des Bunsen-Roscoe'schen Gesetzes für Bromsilbergelatine." Münster, 1898.

obtained the same deviations for slight as for heavy degrees of blackening, and an appreciable effect of preliminary exposure on intense blackening is not to be thought of.

It was therefore desirable to repeat the laboratory experiments. This was made possible by the courtesy of M. Eder, who placed at my disposal the necessary appliances in the *k. k. graphische Lehr und Versuchsanstalt*, and assisted me with many suggestions. The procedure consisted simply in making plates with different (continuous) exposures at different distances from the normal benzine lamp which is used with the Scheiner sensitometer. All of the plates to be compared were cut from the same plate and were developed in the same bath at the same time.

It will suffice here to give a specimen of the results.[1] Equal degrees of blackening were produced in one series of experiments by the following combinations of intensity I and the exposure t:

1		2	
I	$= 81$	I	$= 1$
t	$= 4.8$ secs.	t	$= 785$ secs.
$I \times t$	$= 389$	$I \times t$	$= 785$
$I \times t^{0.86}$	$= 312$	$I \times t^{0.86}$	$= 309$

We see how striking the deviation is from the law of reciprocity. On diminishing the intensity to $\frac{1}{81}$, twice the amount of light is necessary to produce the same blackening. The products $I \times t^{0.86}$, on the contrary, come out equal within the limits of the errors of observation. For the intensity 1 the first trace of blackening appeared with an exposure of 10 seconds, A preliminary exposure of this amount did not alter the results of the experiment, as was expected, and the most dissimilar developers gave the same deviation.

Thus the laboratory experiments, confirm the formula found from the star plates. The bromide of silver gelatine investigated had also the property of employing so much the less of the incident energy for the photographic work, the slower the influx of energy. The diminution of the action of the light

[1] The detailed account of my experiments will soon appear in the publication of the von Kuffner Observatory.

under intermittent exposure, which has been noticed by Abney and more recently by R. Englisch, and which I also found for these highly sensitive plates, is connected with this. In a simple experiment with the aid of Scheiner's sensitometer[1] equal degrees of blackening were produced by
continuous exposures of

96, 72, 48, 24, 12 secs.:

and intermittent exposures of

99, 80, 54, 30, 16.5 secs.

Here the single durations of exposure were to the period of interruption, as

1 : 2.5 ; 1 : 3.1 ; 1 : 4.6 ; 1 : 8.2 ; 1 : 15.0.

The following illustration, which may be useful as a "mechanical analogy" for the further discovery and formulation of the laws applying here, is intended to exhibit the peculiar behavior of the plate: Suppose that a kite, instead of being held by the cord, carries a rather heavy rope, the end of which trails over the ground. If the wind is strong (corresponding to a strong intensity of light) the kite will rise high, only a short portion of the rope will remain on the ground, and the kite will fly rapidly before the wind without much friction for a long distance (corresponding to a strong degree of blackening). If, on the contrary, the wind is light, the kite will remain low and the slight energy of the wind will be for the most part lost in the friction of the long extent of the rope lying on the ground. If the wind is intermittent the kite has so much more time to settle down after every rise, and the motion will be accompanied on the average by the greater friction the longer the intervals between gusts of wind (corresponding to the behavior of the plate under intermittent illumination.)

VON KUFFNER'SCHEN STERNWARTE,
Wien-Ottakring.

[1] This consists of a rotating disk, from which portions have been cut out so as to allow the light to fall on the plate only during a definite fraction of a revolution.