THE VARIATION IN THE BLACKENING OF A PHOTOGRAPHIC PLATE WITH TIME OF EXPOSURE, TOTAL ENERGY REMAINING CONSTANT.[1]

BY P. S. HELMICK.

FOR many years following the discovery of photo-chemical action, it was believed that if the product of the intensity of light producing the exposure and the time of exposure were constant, the resulting photo-chemical effect would be constant. R. Bunsen and H. Roscoe[2] expressed this idea as early as 1862. Subsequently Abney,[3] Miethe,[4] Eder,[5] Michalke and Schiener, Schwarzschild,[6] Lemon,[7] Kron,[8] and others showed variations from this so-called "Reciprocity Law," but directed their attention to the determination of relations between intensity and time which would give constant blackening, rather than finding the variation in the blackening with time, with total energy remaining constant. Abney[9] and Kron[10] seem to have made the only progress in this last-named problem. Both claim that when blackening is plotted against time of exposure, with total energy remaining constant, that the resulting curve will show a maximum; but neither investigator directly obtains this curve.

It has been the purpose of the writer to investigate Abney's and Kron's conclusion, and actually obtain the curve showing the maximum, if it existed. By exposing the plate to different rates of flow of constant light energies, it was believed that some additional knowledge of the physical mechanism in a light-sensitive plate might be gained.

[1] A paper read before the American Physical Society, December, 1916.

[2] Ann. der Phys., 117, 538; 1862.

[3] "Chemical Action and Exposure," Phot. Journ., Oct., 1893; "The Failure of a Photographic Law with Intense Light," J. C. C., 8, 46.

[4] Inaug. Diss. Gottingen., 1899.

[5] Handbuch, Band 2, Jahrbuch, 1899, 457.

[6] Phot. Corr., 1899, 171; Beitrage zur Phot. Photem. d. Gestirne; Astrophys. Journ., 11, 89, 1900.

[7] Astrophys. Journ., 39, 204, 1914.

[8] Ann. der Phys., 41, 755, 1913.

[9] Treatise on Photography, 395, 1901.

[10] Loc. cit.

APPARATUS AND METHOD.

The plates used were coated on special plate glass, and the variations of density due to unevenness of coating were of the order of 1 per cent. The following emulsions were used: Seed 23; Seed 27 G. E.; and Seed Graflex. The sensitiveness of these plates in the camera was roughly 1, 3, and 9.

Two sources of light were used: the integral light from a 4 volt carbon lamp, and green light of wave-length 545 $\mu\mu$ transmitted through a Hilger monochromatic illuminator from a 32 C.P. coil filament tungsten lamp. The plates were exposed in a light-tight box 350 cm. long. The intensity of the light was varied by altering the distance between the plate and the light, and the value of the intensity for any distance was computed by the "inverse square law," as modified by Hyde[11] for finite sources.

Exposures greater than one second were made by a sliding shutter operated by hand, with the aid of a telephone receiver clicking seconds. Shorter exposures were made by a modification of an apparatus used by Wood.[12] Electric contacts attached to a large sector disk rotating at a constant predetermined speed operate an auxiliary sliding shutter, permitting the shutter to be opened just before the revolving sector disk reaches the point where it allows the plate to be exposed, and permanently closing the shutter immediately after the sector disk exposes the plate. The minimum exposure, uniform to 91 per cent.,[13] which this particular apparatus could give with a sector speed of 10 r.p.s. was 1/37,600 second.

Plates were developed for constant time and practically constant temperature in a developer compounded after Brush's formula.[14] Densities were measured in a modification of Lemon's spectrophotometer[15] in which the prism is replaced by two mirrors inclined to one another so as to reflect two beams of light into the observing telescope. One beam of light, reduced in intensity by the interposed plate whose density it was desired to measure, was matched with another beam whose intensity was regulated by the rotation of a nicol prism. The density of the plate in terms of the angle of rotation of the nicol is given by the expression $\text{Log}_{10}\,\text{Sec}^2\,\theta$.[16]

[11] Bull. Bur. Stands., 3, 81, 1907.

[12] Phil. Mag., 6, 577, 1903.

[13] Traite Encyc. de Phot., 1, 436.

[14] PHYS. REV., 31, 243, 1910.

[15] Loc. cit.

[16] A table of $\text{Log}_{10}\,\text{Sec}^2\,\theta$, with differences to 0°.01 has been prepared by the writer, and may be obtained on request from the librarian of the State University of Iowa, Iowa City, Iowa.

RESULTS.

The three different brands of plates were exposed to the integral, or "white" light of the carbon filament lamp, and to the monochromatic green light of wave-length 545 $\mu\mu$, and plotting density and time, a definite

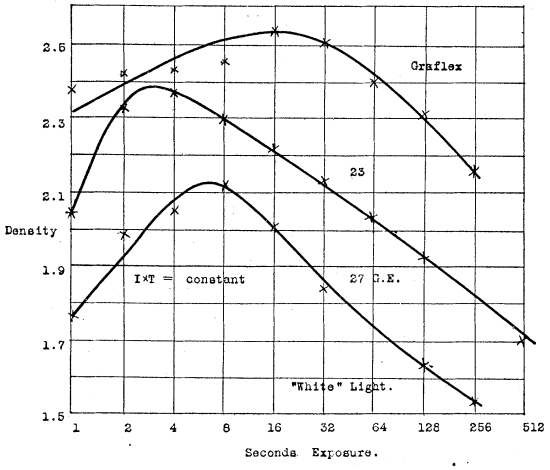

Fig. 1.

maximum density as time varied but with intensity times time constant, was obtained in each case. A few of the curves obtained are shown in the two figures, and are characteristic of all the curves obtained. The

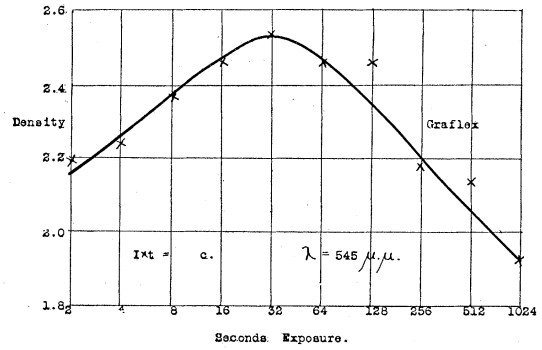

Fig. 2.

curves show that the blackening of a plate is dependent upon the rate of flow of energy, with total energy constant; and that for each brand of plate and quantity of total energy there is a maximum blackening given by a certain rate of flow of energy.

The relative heights of the curves in Fig. 1 are not important, for no fog strip was taken, and the temperature varied a trifle, but the relation between the time of exposure to produce maximum blackening and the speed of the plate seems significant, for with the same value of total energy upon each plate, the positions of the maxima vary as the speeds of the plates. By using this rule, the writer was able to shift the maxima of the curves at will.

SUMMARY.

1. An accurate electric shutter has been designed for photographic exposures.

2. A simple density-determining apparatus has been described.

3. Plates of three different speeds have been exposed to white and to green light. The rate of flow of energy was varied, but the total energy the plate received was kept constant. In every case there was a maximum blackening, and the time of exposure to produce maximum blackening varied as the speed of the plate.

In conclusion, it is a pleasure to acknowledge the encouragement received from the staff of the department of physics of the State University, and particularly from Professor H. L. Dodge.

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