Physics. — "*On a method of determining spectral intensities by means of photography*". By Dr. G. HOLST and Dr. L. HAMBURGER. (Communicated by Prof. H. KAMERLINGH ONNES).

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1. *Introduction.*

The problem of the influence of small amounts of impurities upon the emission of light by a gas, made us look for a method of obtaining in a simple way a general survey of the alterations in the emission of light. Through this means we arrived at a working method very similar to the well known wedge-method [1]) used for determining absorption spectra. Photographs obtained by the latter method are very simple to read [2]), the height of the spectrum serving as a measure for the absorption in the region of wave-lèngths under consideration. In analogy with this we arranged our spectrograph [3]) in such a way that the height of the spectral line forms a measure for the intensity of the incident light. For this purpose we introduced a rotating sector with a radially increasing opening close in front of the slit. The time of illumination increases therefore along the spectral line from below upwards, and with it the blackness. The most intense lines will become the longest on the plate [4]).

2. *Arrangement of the apparatus.*

The sector must be so constructed that there is a simple connection between length of spectral line and the intensity of the incident light. For this it is of the greatest importance to know, how the blackness of the photographic plate depends upon the intensity I and the duration of the illumination t. Under normal circumstances, according to SCHWARZSCHILD, the blackness is measured by the product It^p, where p is about 0.8 [5]). With intermittent light the illumination must be longer to produce the same blackness. The exponent becomes,

[1]) H. KAYSER. Handbuch der Spectroscopie, III. p. 58.

[2]) Comp. for instance the atlases of absorption spectra by H. S. UHLER and R. W. WOOD, or by C. E. KENNETH MEES.

[3]) HILGER quartz-spectrograph C.

[4]) A similar arrangement for sensitometric purposes is used by E. BELIN. Brit. Journ. Phot (53) 630. 1906.

[5]) H. LUX (Zeitsch. f. Bel. wesen 1917 p. 83) finds that in WRATTEN and WAINWRIGHT plates, which we used also, p may vary from $\pm$ 0,83 to 6,3 while according to L. VEGARD Ann. d Phys. (39) 111, 1912 $p = 0{,}89$.

therefore, greater and under certain circumstances may, it seems, become 1., so that ROSCOE and BUNSEN's law would become valid. According to measurements made by A. E. WEBER [1]) this would be the case when the number of revolutions of the sector is more than 120 per minute. A similar result was obtained by F. ECKERT and R. PUMMERER [2]) and also by H. E. HOWE [3]). A. ODENCRANTS [4]) also finds an increase of p, but he does not consider that BUNSEN and ROSCOE's law may be applied. There is thus still some uncertainty as to the foundations upon which our method rests. This is, moreover, increased by the fact that we determine the ends of the line that are still just visible, and in consequence measure in the field of sub-illumination. For the sake of simplicity we have, therefore, in constructing the sector assumed the validity of BUNSEN and ROSCOE's law, and subsequently investigated by measurements in how far this assumption is borne out.

The first sector was so constructed, that the length of the spectral line was proportional to the intensity of the light. The intensity-variations along the line were then, however, too small to be easily measurable. We therefore proceeded to make a sector with which the length of the lines becomes proportional to the logarithm of the intensity (fig. I), with this we obtained satisfactory results. For the sector used

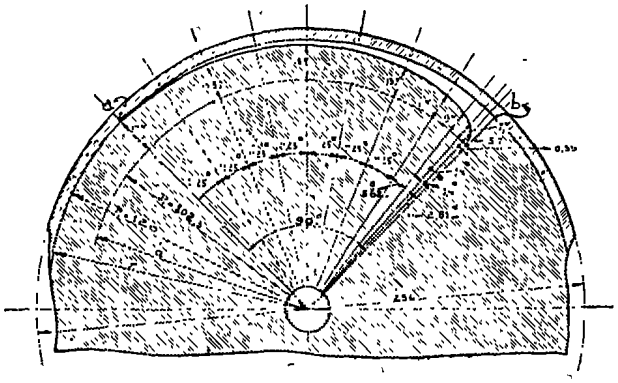

Fig. 1.

$$\log \frac{I_2}{I_1} = 1{,}5\,(l_2 - l_1)$$

where l means the length of the spectral line [5]).

3. *A few measurements.*

In order to test the reliability of our method we carried out

[1]) WEBER. Ann. d. Phys. (45) 801. 1914.
[2]) ECKERT and PUMMERER. Zeitsch. f. physik. Chem. (87) 605. 1914.
[3]) HOWE. Phys. Rev. 8, 674, (1916).
[4]) ODENCRANTS Zeitsch. f. Wissensch. Phot. (16) 69, 111. 1916.
[5]) For further particulars cf HAMBURGER, Diss. Delft 1917.

various checking measurements, some of which made with a mercury arc lamp we shall detail here [1]). The arrangement of the apparatus is shown in fig. 2.

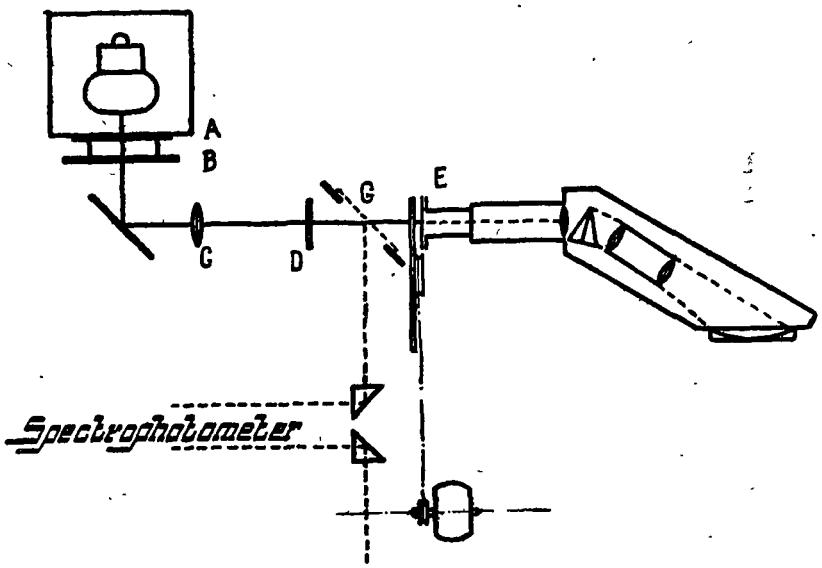

Fig. 2.

Under the mercury lamp a plate of ground-glass was introduced. A second similar plate B was illuminated by A. The illumination of B was completely uniform. An image of B was thrown upon a 3rd ground glass plate D by means of a lens C. The slit in the HILGER-quartz spectrograph was completely uniformly illuminated by D. The sector was placed close in front of E. At G a mirror was placed which could be removed. By means of a spectro-photometer of the KÖNIG-MARTENS type the illumination of D could be measured in the light of the green mercury line.

The measurements proceeded as follows. When the mercury lamp had become constant, the illumination of D was determined by the spectro-photometer. Then the mirror G was removed and the plate illuminated for three minutes. After this D was again measured with the photometer. The illumination was then changed by reducing the lens C with a diaphragm. The measurements were repeated and a new photograph taken.

In this way we made several series of readings with different intensities.

The differences in length of the spectral lines were measured by placing the negatives on top of each other and shifting them until

[1]) Other checking measurements carried out previously may be found in Diss. HAMBURGER p. 87, 91, 92, 96, 108 and 113.

the tops of the lines to be compared were in a line beside each other. The distance between the dark lower ends was then measured. As in this way the two lines could be compared over a fairly great length and both appear on the same back ground, the difference in length can be pretty correctly measured. Not more accurately however than to about 0.2^5 mm.

With intensity-ratios of 1 : 3,95 : 8,80 as measured by the spectro-photometer we found in the mean differences of length of 3,7 and 6,5 mm. Calculating from these the intensity-ratios we find $1 : 3{,}6 : 9{,}4^6$. These deviations correspond to difference in length of $0{,}2^7$ and 0,2 mm. and are therefore of the order of accuracy with which the length of the lines can be determined. We could not find a systematic difference for the various lines; the lines measured were 5191—5170, 5461, 4359, 4047 and 3650.

We also tried the sector for much greater intensity-ratios, for instance 1 : 60 and 1 : 100. In these cases the short line was always found too short. It is certainly not surprising that the sector is not correct in the extreme fields. For some investigations, however, these are not of importance; in which cases the method may be usefully applied. The method [1]) was not sufficiently accurate for us to be in a position to decide as to the validity of BUNSEN and ROSCOE's law.

To summarize the advantages and disadvantages of this method we may say: it gives on a single photographic plate an easily read image of the spectral intensity including the ultraviolet part of the spectrum; it enables us to determine quantitatively changes in the intensity, the measurements do not cost much time and require only a few photographic plates. The accuracy of the method, however, is not more than about 10 %. Greater intensity-ratios than about 1 : 20 cannot very well be determined by it. These characteristics of the method make it very suitable for preliminary investigations, which can subsequently be worked out in detail by a less rapid and usually less easily readable method. Researches of this kind concerning the emission of light by gases and their mixtures, have been made by one of us which have demonstrated its usefulness.

It remains to express our sincere thanks to Dr. G. L. F. PHILIPS for the friendliness with which he enabled us to carry out this research.

Eindhoven. *Laboratories of Philips's Incandescent lamp factories.*

[1]) As a matter of fact all photographic methods have only a relatively small accuracy. A. E. WEBER (l. c.) says for instance that if abnormal values are excluded a possible error of about 8 % must be reckoned with.