

## THE ABSORPTION OF ULTRA-VIOLET LIGHT BY OXYGEN, WATER VAPOR AND QUARTZ\*

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### ABSTRACT

Quantitative measurements were made of the absorption of light by oxygen, water vapor and crystalline quartz in the spectral region 1850 to 2300A, by means of a quartz spectrograph and a recording densitometer. Defining the absorption coefficient  $\alpha$  by  $I = I_0 10^{-\alpha d}$  where  $d$  is the distance in cms, values of  $\alpha$  were obtained for oxygen at atmospheric pressure in tubes up to 5 meters in length, which showed the peaks of absorption due to the Schumann-Runge band system below 1970A. From 2000 to 2100A the absorption appeared continuous with no marked peaks,  $\alpha$  being 0.00025, 0.00032 and 0.00050 at 2100, 2050 and 2000A respectively. The values of  $\alpha$  for saturated water vapor at 25°C were 0.0005, 0.0013, 0.003 for wave-lengths 2050, 1950 and 1900A. For a specimen of crystalline quartz 2.5 cm thick  $\alpha$  was found to be 0.086, 0.11, 0.13 and 0.17 for wave-lengths 2040, 2000, 1940 and 1870A.

**I**N THE present investigation the light absorption coefficients of oxygen, water vapor and crystalline quartz have been measured in the spectral region from 2300 to 1850A. Kreuzler<sup>1</sup> obtained the absorption coefficients of oxygen at 1860 and 1930A, and Pflüger<sup>2</sup> and Tsukamoto<sup>3</sup> made measurements on crystalline quartz from 2100 to 1850A. No measurements on water vapor seem to be available.

The transmissions of the various substances under investigation were measured by the photographic method described by Ham, Fehr and Bitner<sup>4</sup> and others. By means of a quartz spectrograph, five exposures of equal time were made on the same plate, four with wire screens having transmissions of 100 (no screen) 58, 32 and 15 percent inserted between the spectrograph and the source, and the fifth with the absorbing substance. The opacities of the lines in the five spectra were measured by a recording densitometer. Several prominent lines were selected in the region under investigation and the opacities of these were plotted as functions of the transmission. Then knowing the opacity of each line in the spectrum taken through the absorbing substance the corresponding transmission could be obtained. The absorption coefficient  $\alpha$  defined by the equation

$$I = I_0 10^{-\alpha d} \tag{1}$$

where  $I/I_0$  is the transmission and  $d$  is the thickness of the absorbing substance in centimeters was calculated from the observed transmission. Wire screens

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<sup>1</sup> H. Kreuzler, Ann. d. Physik **6**, 412 (1901).

<sup>2</sup> A. Pflüger, Phys. Zeits. **5**, 215 (1904).

<sup>3</sup> M. K. Tsukamoto, Rev. d'Optique **7**, 89 (1928).

<sup>4</sup> Ham, Fehr, Bitner, J. Frank. Inst. **178**, 299 (1914).

ranging from 18 to 150 mesh per inch calibrated in the ultra-violet by means of a monochromatic illuminator and a quartz photoelectric cell, and in the visible by a Nutting spectrophotometer, were used to calibrate the plates, the conditions under which the screens were calibrated were made as nearly identical as possible to those under which they were used. The transmission of each screen was found to be constant from 2536 to 4046Å and in the visible within the limit of error which amounted to about 3 percent. Below 2536Å the transmission was not measured, but was assumed to be the same as that of the longer wave-lengths. As Schumann plates required a less time of exposure than ordinary plates in the region 1850–2000Å they were used in all cases except for the 11.7 cm piece of quartz. Due, however, to the irregularities and large grain structure in the emulsion, the errors in the transmis-

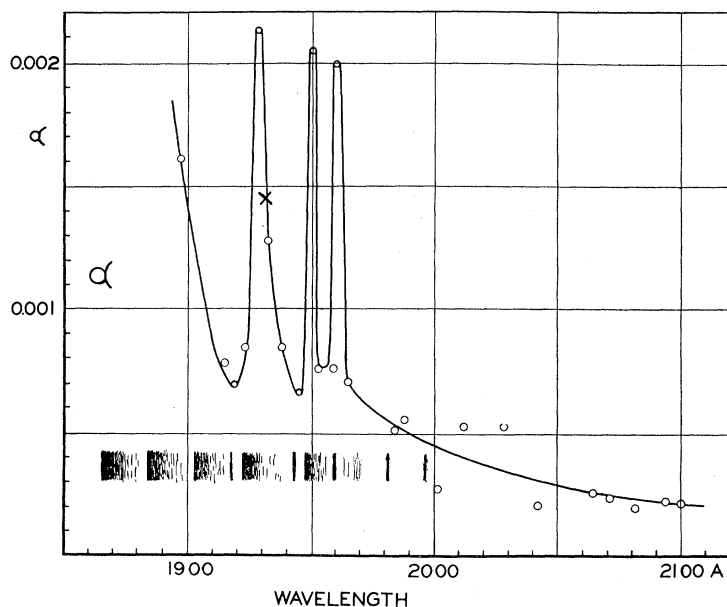


Fig. 1. Light absorption coefficient  $\alpha$  of oxygen. Circles indicate values obtained in present investigation, while the cross indicates the value found by Kreuzler.

sion values obtained from these plates amounted to about 10 percent. A condensed iron spark was used as a source in the measurements on oxygen and a silver spark on water vapor and quartz.

*Oxygen.* Commercial oxygen, purified with heated platinum black and phosphorus pentoxide, was passed into the absorption chamber which previously had been thoroughly evacuated and dried. The absorption chamber consisted of a Pyrex tube 3.5 cm in diameter and 511 cm long; quartz windows were fastened on the ends with sealing wax. Four calibration spectra were taken through the evacuated tube and a spectrum through the tube filled with oxygen at atmospheric pressure. The values of  $\alpha$  for oxygen are shown in Fig. 1, by the circles and smooth curve. The cross is the value given

by Kreusler.<sup>1</sup> The Schumann-Runge band absorption system of oxygen, including a few lines of undetermined origin, is sketched in Fig. 1 from a plate taken with a five meter thickness of oxygen using the continuous spectrum of mercury as a source in this region. The wave-lengths of the heads of the bands agreed with those given by Duclaux and Jeantet,<sup>5</sup> S. Leifson<sup>6</sup> and by L. and E. Bloch.<sup>7</sup> The curve for  $\alpha$  gives only a partial reproduction of the bands, it cannot be considered as a complete absorption curve which gives all the details of the band structure. For this purpose greater dispersion and

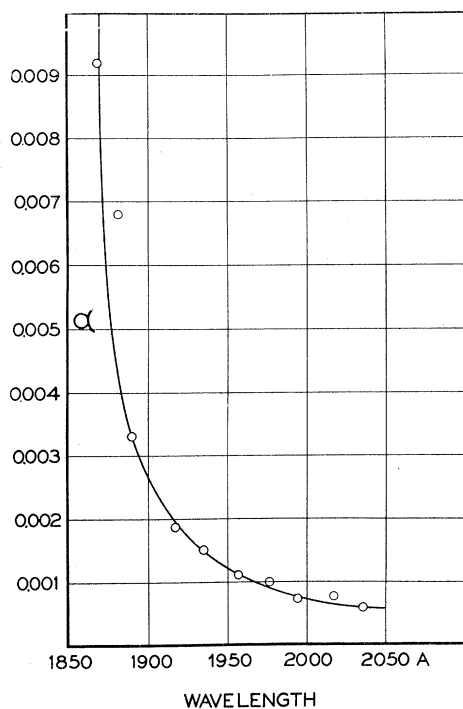


Fig. 2. Light absorption coefficient  $\alpha$  of water vapor.

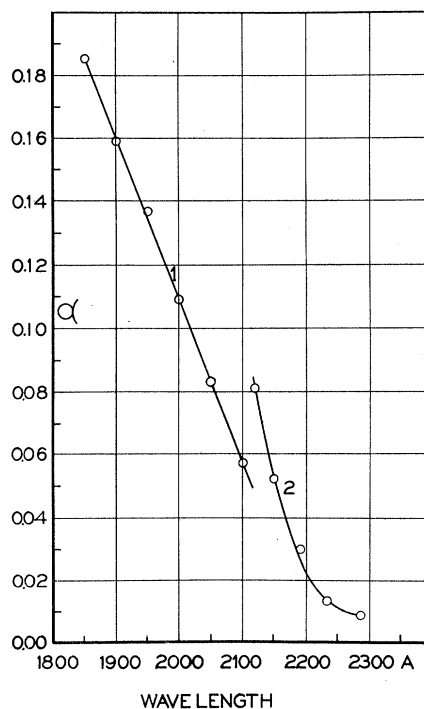


Fig. 3. Light absorption coefficient  $\alpha$  of quartz; curve 1 represents values for a 2.5 cm piece of quartz and curve 2 values for a 11.7 cm piece.

a more extended series of observations would be necessary. For example it was noticed that two iron lines at about 1959 and 1960A were of approximately the same intensity when the tube was evacuated, but when the tube was filled with oxygen  $\lambda$ 1951 almost vanished whereas  $\lambda$ 1950 was little changed.

*Water vapor.* The values of the absorption coefficients of water vapor are given in Fig. 2. To obtain these the exposures were taken with the various

<sup>5</sup> Duclaux and Jeantet, *Comptes rendus* **173**, 581 (1921).  
<sup>6</sup> S. Leifson, *Astrophys. J.* **63**, 73 (1926).  
<sup>7</sup> L. and E. Bloch, *Comptes rendus* **158**, 1161 (1914).

screens through the evacuated and thoroughly dried tube; the tube was then connected with a bulb containing distilled water, the bulb being slightly heated until enough vapor entered the tube to condense on the walls. The windows were heated with a flame in order to remove any condensed water; the slight heating kept them dry for a longer time than was necessary for the exposure. A path of 241 cm was used for the absorption from 2050 to 1920A, and from 1920 to 1860A the path was 29 cm.

*Quartz.* Measurements were made on two pieces of crystalline quartz, optically good, one 2.5 cm and the other 11.7 cm thick. In order to obtain consistent results it was found necessary to clean carefully the quartz with alcohol before each set of exposures. Fig. 3, curve 1 gives the values of  $\alpha$ , corrected for surface reflection for the 2.5 cm piece and curve 2 for the 11.7 cm piece. In the spectrum region around 2100A where the two curves can be compared, they show different values of  $\alpha$ , this was a real difference in the two pieces of quartz. Tsukamoto<sup>3</sup> also found different absorption values for various samples of quartz.

It is of interest to calculate the absorption of ultra-violet light in a quartz spectrograph. For example, the small quartz spectrograph, Hilger type E31, has two quartz lenses of a total thickness of 0.55 cm, a 60° quartz prism whose base measures 2 cm approximately, and an air path of about 40 cm from the slit to the photographic plate. It was found by calculation from the data of Figs. 1 and 3 that for  $\lambda 1860$  the absorption of the quartz in the spectrograph was 50 percent and of the air was 17 percent. For  $\lambda 1900$  the respective values were 31 and 3 percent, for  $\lambda 2000$  23 and 1 percent and for  $\lambda 2100$  16 and 0.5 percent.

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