A SIMPLE CYLINDRICAL LENS SPECTROGRAPH FOR THE OPTICAL DETERMINATION OF THE CONCENTRATION OF OZONE IN THE ATMOSPHERIC LAYERS NEAR THE GROUND

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The optical absorption of ozone in the region 3150 to 2200 Å has been used by a number of workers for the determination of the amount of ozone in the atmosphere, since the pioneer use of it for this purpose by Fabry and Buisson1 in 1920. Buisson, Jousseran and Rouard in France,2 Götz and Ladenburg,3 and Götz and Maier-Leibnitz4 in Switzerland have determined the relative attenuations of ultra-violet light of different wave-lengths by exposing similar spectrographs at different distances from a source of radiation and calculated from the results that the amount of ozone normally present in the air-layers near the ground is in the neighbourhood of $2 \times 10^{-3}$ cm. at N.T.P. per kilometre length of air. The present note describes a simple prism spectrograph for the photometric determination of the amount of ozone in the air-layers near the ground and the preliminary results of some measurements made with it at Poona.

Description of the Spectrograph

The usual methods of photographing the spectrum of a distant source of light of small angular extent are to throw an image of the source on the slit of the spectrograph by means of a cylindrical lens so that the point-image is elongated into a line, or to move the photographic plate in a direction perpendicular to the length of the spectrum. For some purposes, an objective prism spectrograph in which the slit and collimator are dispensed with, offers advantages but the point-images obtained with it are not convenient for photometric purposes. If the spherical camera lens of the objective prism spectrograph is replaced by a cylindrical lens with its axis parallel to the refracting edge of the prism, a spectrum with the usual appearance can be obtained, and if an optical wedge is added near the photographic plate with the slope of the wedge parallel to the length of the spectral lines the comparative intensities of the lines in the spectrum can be easily determined.
A spectrograph constructed on this principle is shown in Figs. 1 and 2. In Fig. 1, T is a cylindrical tube for directing the instrument towards the source and preventing light from other undesired sources from falling on the prism, P is a Cornu prism of quartz, L a cylindrical lens, W an optical wedge and A the photographic plate. In Fig. 2, a sighting tube is shown parallel to the tube T which helps to direct the instrument in the proper direction.

The instrument was used to determine the ozone near ground level at Poona on a few days in the clear season of 1937. A quartz mercury arc lamp was used as the source of light and was placed on the roof of the Fergusson College Physical Laboratory. The current through the arc was kept constant with the help of a rheostat and ammeter and a fan was used to drive away any accumulation of ozone in the neighbourhood of the arc. The spectrum of the arc was photographed from three different places: (1) From the Fergusson College Hospital, distant 0.3 km. from the arc; (2) From the tower of the Meteorological Office, distant 1.6 km.; (3) From the Parnakuti hill, distant 4.8 km. The times of exposure varied from a few seconds at the first distance to 5 hrs. at the last. The observations were usually made on nights when the evening sea-breeze had cleared the haze over the city and its environs.

The nature of the photographs obtained without the wedge will be seen from Fig. 3 (a) in which are shown the spectra of a quartz mercury arc at distances of 0.3, 1.6 and 4.8 km. respectively. The appearance of the spectra when the quartz wedge is in position is shown in Fig. 3 (b).

The method of calculating the amount of ozone is briefly outlined below:
Let $I_1$ be the intensity of light of wave-length $\lambda_1$ received at a distance $r$ from the source. Then

$$I_1 = \frac{L_1}{4\pi r^2} 10^{-\left(a_1 x + \beta_1 + \gamma_1\right) r}$$

(1)

when $L_1$ is the power radiated by the source in light of wave-length $\lambda_1$, $x$ is the amount of ozone in the atmosphere per unit length of path, $a_1$ is the decimal absorption coefficient of ozone, $\beta_1$ the attenuation of light per unit length of path due to molecular scattering and $\gamma_1$ the attenuation coefficient due to dust or other suspended particles.

Similarly, the intensity $I_2$ of the light of wave-length $\lambda_2$ is given by

$$I_2 = \frac{L_2}{4\pi r^2} 10^{-\left(a_2 x + \beta_2 + \gamma_2\right) r}$$

(2)

From (1) and (2)

$$\frac{I_1}{I_2} = \frac{L_1}{L_2} 10^{-\left(a_1 - a_2\right) x r - \left(\beta_1 - \beta_2\right) r - \left(\gamma_1 - \gamma_2\right) r}.$$  

(3)

Similarly for another distance $r'$

$$\frac{I'_1}{I'_2} = \frac{L'_1}{L'_2} 10^{-\left(a_1 - a_2\right) x r' - \left(\beta_1 - \beta_2\right) r' - \left(\gamma_1 - \gamma_2\right) r'}.$$  

(4)

From (3) and (4)

$$x = \frac{\log I_2 - \log I'_2 - (\log I_1 - \log I'_1) + \left(\beta_2 - \beta_1\right) (r - r') + \left(\gamma_2 - \gamma_1\right) (r - r')}{{(a_1 - a_2) (r - r')}}$$

(5)

If the wedge constants for the wave-lengths $\lambda_1$ and $\lambda_2$ are known, the ratios $I_1/I'_1$ and $I_2/I'_2$ can be calculated easily from the lengths of the lines in the wedge spectrum, $\beta_1$ and $\beta_2$ can be determined from Rayleigh's scattering formula with the correction for the depolarisation of the scattered light, and the difference $\lambda_2 - \lambda_1$ is negligible compared with $(a_2 - a_1) x$ and $(\beta_2 - \beta_1)$, particularly if $\lambda_1$ and $\lambda_2$ are near each other and one of them is outside the region of ozone absorption and the other within it, and the atmosphere does not contain large chemical impurities. In Poona, on days when the evening sea-breeze sets in, the atmosphere is generally free from dust and haze for a few hours after sunset.

For the preliminary measurements at Poona, the quartz wedge of the Dobson spectrograph was used. This has a wedge-constant of about 1.38 per centimetre in the ultra-violet region near 3000 Å. The amounts of ozone obtained at Poona varied from 1 to $5 \times 10^{-3}$ cm. ozone at N.T.P. per kilometre of path which is of the same order of quantities as those obtained in
Fig. 2.—Photograph of the cylindrical lens spectrograph
Fig. 3 (a).—Spectrum of the mercury arc taken with a cylindrical lens spectrograph at different distances from the source.

Fig. 3 (b).—Spectrum of a quartz mercury arc taken with a cylindrical lens spectrograph and an optical wedge.
France and Switzerland. For an accurate determination of the daily variations in the amount of ozone a wedge with a smaller constant should be used. Arrangements are being made to obtain a suitable wedge and extend the observations.

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REFERENCES


