ON THE PLOTNIKOW EFFECT OR LONGITUDINAL LIGHT SCATTERING IN LIQUIDS.

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1. *Introduction.*

IT has been observed by Plotnikow and his collaborators[1] that when a narrow beam of light is passed through a column of liquid, such as alcohol, acetic acid, petrol-ether, water, castor-oil, ethylene glycol, etc., and is received on a photographic plate, there appears on the plate besides the central spot given by the undeviated pencil, a circular halo surrounding it. This halo is bright enough to be seen by the naked eye. According to Plotnikow, this longitudinal light-scattering (Plotnikow effect) is a universal phenomenon exhibited by almost all liquids and liquid mixtures. He further postulates the presence of huge molecular aggregates of size comparable with the wavelength of light to account for this effect. The longer the wavelength of the light used, the more intense is the longitudinal scattering. It is also observed that the effect is most intense in the case of viscous liquids, such as castor-oil, ethylene glycol, transformer oil, etc.

It is a well-known fact that dust particles in a liquid give rise to an enormous amount of light scattering. In all experiments on the scattering of light, the removal of dust particles from the fluid is one of the most important precautions to be taken. Surprisingly enough in none of Plotnikow's papers is any reference found to this important question. Experimentally as well as theoretically from the fundamental equations of electro-magnetic theory, it has been shown[2] that when large suspended particles are present, the scattering in the forward direction, *i.e.*, in the direction of the primary beam, is greatly enhanced. Moreover, the

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[1] J. Plotnikow and L. Splait, *Physikal Z.*, **31**, 369, 1930.
J. Plotnikow and S. Nishigishi, *Physikal Z.*, **32**, 434, 1931.
J. Plotnikow, *Strahlenther*, **49**, 339, 1934.

[2] C. V. Raman, *Molecular Scattering of Light*, 1922.
K. R. Ramanathan, *Phil. Mag.*, **46**, 543, 1923.
B. B. Ray, *Proceedings of the Indian Association for the Cultivation of Science*, **8**, 221, 1923.
W. Shoulejkin, *Phil. Mag.*, **48**, 307, 1924.

spectroscopic character of the scattered light is different in different directions. The light scattered in the forward direction contains more of the red portion of the spectrum than that in the transverse direction.

It seems very difficult to accept Plotnikow's suggestion that, in ordinary liquids, large aggregates of molecules are present, the size of which is comparable with the wavelength of light, in order to explain the halation observed by him in directions adjacent to the primary beam. Such huge aggregates can hardly exist in ordinary liquids, though of course, they are known to be present in liquid crystals. The present investigation was undertaken to examine whether ordinary liquids exhibit the Plotnikow phenomenon to the same extent after being freed from dust.

2. *Observations with Liquids not free from Dust.*

The light from a 20-ampere carbon arc was rendered parallel and was allowed to pass through a narrow tube, 15 cm. in length and 6 mm. in diameter, provided with a screen at one end. The light after passing through another circular aperture of diameter about 3 mm. entered the column of liquid contained in a glass cell (8 cm. $\times$ 5 cm. $\times$ 5 cm.). The direct light was cut off by a piece of carbon rod held axially. The cell was carefully cleaned and was then filled with various liquids, one after another : acetic acid, ethyl alcohol, methyl alcohol, water, petrol-ether, ethylene glycol and castor-oil were used in succession. The observations were made in a dark room. When the transmitted light was received on a ground glass plate, a general halation was observed surrounding the centre which was most intense in the case of viscous liquids such as castor-oil and ethylene glycol.

When the track of the beam inside the liquid was viewed through a microscope in a direction slightly inclined to the transmitted beam, numerous dust particles were seen moving about and acting as scattering centres. The spectroscopic character of the scattered light was found to be different in different directions. When the direction of observation was nearly against the direction of the incident beam, the suspended dust particles were much more conspicuous and the colour was much less blue than along a transverse direction. On the other hand, in directions backward to that of propagation of the incident light, the particles were less conspicuous and the blue colour of the scattered light was more saturated than in transverse directions.

From these observations, it became clear that the major part of the halation was due to dust. Usually, viscous liquids contain more of suspended dust and colloidal particles. Consequently, the scattering in the forward direction should be more intense and less blue in such cases, as was actually found.

3. *Experiments with Dust-free Liquids.*

Two flat pyrex discs were fused on to the flat and parallel ends of a cylindrical pyrex tube 10 cm. in length and 3 cm. in diameter. This was connected to a larger bulb through a side tube and carefully cleaned and dried. The bulb was filled with pure ethylene glycol and the whole system evacuated and sealed off. The liquid was then distilled from the bulb to the observation tube. After the first distillation, this tube containing the liquid was placed in the path of the beam of light in place of the rectangular cell. The flat ends were carefully cleaned outside. On examining the transmitted light it was found that the brightness of the halation was distinctly less than in the case of the liquid before distillation. The process of slow distillation and washing the liquid back to the bulb was then carried out a large number of times till the liquid in the observation tube was completely free from dust. After each distillation, a test was made, and it was found that the forward scattering diminished as the amount of dust decreased and that the spectroscopic character of the light scattered in the forward direction approached closer and closer to that of the transversely scattered light. Finally, when all the dust was removed, the general halation in the forward direction completely disappeared, and the colour of the scattered light was not visibly different in different directions. The introduction of a coloured filter, *e.g.*, a red glass or a green glass placed in the path of the incident light weakened the scattered light to the same extent in all directions. It should be mentioned that the slight imperfections of the ends of the observation tube gave rise to a certain amount of diffused light. This could easily be distinguished, however, from the effect arising within the liquid, and its magnitude and distribution could be ascertained by repeating the experiment with the tube empty after careful cleaning and drying.

The experiments were repeated with acetic acid, ethyl alcohol and petrol-ether as scattering substances. No effect was observed in any of the cases, except that due to the imperfections of the ends of the vessel, provided the liquids were absolutely free from dust. The track of the beam inside the liquid was seen only with difficulty in the vicinity of the primary beam in these cases. Attempts were made to distil castor-oil with the aid of Hickmann's vacuum still so as to get it pure and dust-free for observation of longitudinal scattering but without success. Further experimental investigations with highly viscous liquids of high boiling point are in progress.

In conclusion, the author wishes to thank Sir C. V. Raman, Kt., F.R.S., N.L., for suggesting the problem and for his valuable help and guidance during the course of this investigation.

4. *Summary.*

Experiments on the "Plotnikow" effect or the longitudinal light scattering in liquids were carried out with liquids not free from dust and also with liquids free from dust. The effect was observed conspicuously in the case of dusty liquids. The effect completely disappeared in the liquids so far examined when they were freed from dust by repeated distillation in vacuo. It thus seems clear that the Plotnikow effect is not a molecular phenomenon but is due to the presence of dust.