### The Splitting of Spectral Lines at Scattering of Light by Liquids.

As was pointed out in my previous communication (see NATURE, Aug. 9, p. 201), when light is scattered by liquids or crystals, there can be observed a splitting of spectral lines which may be ascribed to the influence of elastic heat waves. In the case of strongly scattering liquids, the change of the frequency is given by the following equation :

$$\nu = \nu_0 \left( 1 \pm 2n\frac{v}{c} \sin \frac{\theta}{2} \right) \quad n = 0,\ 1,\ 2,\ 3,\ \ldots$$

where $\nu_0$ is frequency of the incident light, $v$ and $c$ are velocities of sound and light in the medium, $\theta$ is the angle between the incident and scattered rays. It is interesting to note that the length of sound waves to which this splitting may be ascribed is of the same order of magnitude as the wave-length of light.

I wish to give here some details regarding this phenomenon and also to describe some new experiments.

The observed displacement of components does not strictly follow the above equation. In all cases, with the exception of aniline, the observed values are somewhat greater than the calculated ones. In these calculations, the experimental values for the velocity of sound obtained chiefly by the Kundt method were used. However, the velocities of sound calculated from the coefficient of compressibility and density of liquids also do not give values which are in full agreement with experiment.

The intensities of 'red' and 'blue' components are, as it seems, nearly equal. The intensities of inner components (that is, corresponding to $n=1$ in the above equation) are greater than those of the outer ones (corresponding to $n=2, 3, \ldots$), and the intensity of the undisplaced line is still greater but perhaps is not greater than twice the intensity of the nearest displaced components. The greatest relative intensity of the undisplaced line was observed in benzene and water. Perhaps the increased value of the intensity of this line is due, at least partly, to dust and contamination of the liquids, which did not in these experiments undergo a special purification (this refers particularly to water, for which the intensity of scattered light is small). It must be remembered that it is very difficult to judge the relative intensity of lines from spectrograms obtained with the echelon grating.

The width of displaced as well as of undisplaced components is not the same for different liquids. It is less in benzene, which gives the displaced lines most distinctly ; on the other hand, ethyl alcohol and ethyl ether give diffuse, barely distinguishable lines. In benzene the width of components may be estimated at 0·025 A: Between all the components there is a continuous spectrum.

Some experiments on polarisation of scattered light were made with benzene. When the incident light is not polarised, the undisplaced and the two neighbouring displaced components, that is, lines corresponding to $n=0$ and $n=1$ in the above equation, are strongly polarised, the electric vector being perpendicular to the direction of the incident beam. On the contrary, the other components, that is, corresponding to $n=2, 3, \ldots$, are, as it seems, almost quite unpolarised.

I wish to return to the question of the maximum possible value of $n$, or the maximum possible displacement of components. If the appearance of these displaced components is due to the diffraction by 'heat wave gratings' of harmonics, the value of $n$ will be limited by the fact that in liquids as well

as in solids it is possible to assume a limiting maximum frequency of Debye's 'acoustic spectrum' which corresponds to a wave-length equal to twice the mean distance between molecules. If this distance is of the order of 3–4 A., the limiting frequency will be of the order of $2$–$2\cdot5 \times 10^{12}$ sec.$^{-1}$ and will produce a displacement of about 15 A. Maybe this is the cause of the broadening of the scattered lines in both directions extending nearly to the above distance which was noticed in liquids (for example in benzene) by many observers (Cabannes et Daure, *C.R.*, **186**, p. 1533; 1928; Raman, *Ind. Jour. of Phys.*, **4**, p. 399; 1928; Gerlach, *Ann. d. Phys.*, **5**, p. 301; 1929). Experiments which are now in progress seem to support this view.

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### The Atomic Diameters of Hydrogen and the Inert Gases with respect to Electrons of Very Low Velocity.

THE wave-mechanical treatment of the problem of the scattering of $\alpha$-particles by neutral atoms has been given by Sommerfeld (" Wave-Mechanics ", pp. 192-199). To simplify the calculations he assumes that all the electrons in the atom under consideration are concentrated in the $K$-shell and have no influence on one another. With similar assumptions, but by a somewhat different procedure, we have made an approximate calculation of the scattering of very slow *electrons* by neutral atoms. This has enabled us to calculate the atomic diameters of hydrogen, helium, neon, and argon with respect to electrons of vanishingly small velocity (0-volt electrons). We obtain the surprising result that the atomic diameters of these gases should vary *inversely* with respect to their atomic numbers. It is obvious that this result should come out most correctly by experiment in the relative magnitudes of the atomic diameters of hydrogen and helium, as only the $K$-shell exists in their case, and that the error introduced by the above assumptions as applied to the present problem will become much greater as we pass to the higher atomic numbers owing to the greater number of electrons far outside the $K$-shell.

Actual experimental values of these atomic diameters with respect to 0-volt electrons have not yet been obtained. The best available data for comparison are those obtained from experiments by Townsend and Bailey. In Fig. 10, p. 28, of Townsend's " Motion of Electrons in Gases " (Oxford) curves are given which exhibit the relationship between the mean free paths of electrons of varying velocity in hydrogen, helium, neon, and argon. The velocity of the electrons ranges from 2 volts to 1/9 volt in this diagram for the case of hydrogen and helium, but only from 2 volts to slightly below 1 volt in the case of argon and neon. At an electronic velocity of 1 volt the mean free paths are in the ratios $3 : 8 : 40 : 140$ for hydrogen, helium, neon, and argon respectively, of which the atomic numbers are 1, 2, 10, 18. All the curves are divergent towards lower velocities, so that these ratios would become correspondingly larger below 1 volt.

Townsend and Bailey showed in 1921 that the mean free path in argon reaches a maximum at 0·39 volt (as has recently been verified by Ramsauer and Kollath : see NATURE, Mar. 15, 1930, p. 427), and, as there is reason for believing that a maximum occurs in the case of all gases, extrapolation of these curves towards lower velocities is impossible. Since we may take the mean free paths as inversely proportional to the atomic cross-section or the square of the atomic