LETTERS TO THE EDITORS

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Quantum Theory of X-Ray Reflexion

In a memoir which appeared in 1926, Laue[1] showed by purely classical reasoning that the X-rays scattered by elastic solid waves of thermal origin in a crystal have the frequency $\nu \pm \nu^*$, ν being the primary X-ray frequency and ν^* the frequency of the elastic waves. He evaluated I_ν and $I_{\nu \pm \nu^*}$, these being respectively the intensities of the reflexion and the scattering by any assigned set of lattice planes in the crystal. The value of $I_{\nu \pm \nu^*}$ for any specified direction of scattering may be found by assigning the appropriate wave-length and orientation to the elastic waves in Laue's formula. The ratio $I_\nu / I_{\nu \pm \nu^*}$ comes out, as might naturally be expected, to be of the order N, this being the total number of atoms in the irradiated solid. Even for a tiny crystal only 1μ in size, the ratio is thus of the order 10^{11}. In other words, the scattering in any specified direction by the lattice planes has an intensity wholly negligible in comparison with that of the coherent reflexion by the same planes.

In an article published in *Current Science* of April 1940, and in a series of three papers following it in the *Proceedings of the Indian Academy of Sciences* for May 1940, experimental evidence was presented showing that the lattice planes in a crystal are capable of giving a second kind of specular reflexion which differs from the reflexions of the classical type in being of a dynamic character and having an altered frequency, besides obeying different geometric laws. Experimental evidence was also presented showing that these reflexions are due to the excitation of the *optical* vibrations of the crystal lattice, and reasons were given for the view that this new type of reflexion is a quantum-mechanical effect.

Other alternative theories of the phenomenon have appeared which, in our view, are neither in accord with accepted physical principles nor with the experimental facts emerging from our investigations. We may, in particular, refer to a view which has been repeatedly expressed [2,3], namely, that the effects observed are diffuse maxima in the scattering of X-rays by elastic waves of thermal origin. This suggestion is, in our opinion, completely contradicted by the observed intensity of the reflexions and their persistence over a large range of settings of the crystal. As shown by our investigations, the intensity ratio between the unmodified and modified reflexions of monochromatic X-rays varies greatly with the crystal, its setting and with the spacing studied; it is generally of the order 1000 : 1, but certainly nothing like 10^{11}. The actual facts of the case can only be understood on the view that we are dealing with the optical vibrations of the crystal lattice; these produce large dynamic variations of the structure amplitudes and negligible distortions of the lattice, unlike the elastic waves, in respect of which the situation is exactly the opposite.

As is well understood at the present time, classical optics and quantum mechanics are mutually complementary and not contradictory. Classical optics indicates that a crystal in which the interpenetrating lattices vibrate with reference to each other would give intense specular reflexions of X-rays with an altered frequency. When, therefore, such an effect is actually observed, it is a legitimate inference that the changes in the energy level of the crystal associated with such a reflexion are to be regarded as induced by the incident radiation itself; in other words, that the intensity of the reflexions is determined by quantum dynamics and not by the classical mechanics. This view led us to predict[4] that the intensity of the modified reflexions by the (111) planes of diamond would remain unaffected by cooling the crystal down to liquid air temperatures. This prediction has been completely confirmed by our experiments[5]. Neither the high elasticity of diamond nor the existence of a zero-point energy appear to us to be in any way relevant as an explanation of the observed facts[6].

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[3] Lonsdale, NATURE, **146**, 806 (1940).
[4] Raman and Nilakantan, *Proc. Ind. Acad. Sci.*, **11**, 396 (1940).
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The Lightning and Spark Discharges

It has recently been pointed out[1] that though the charge leaving the cloud in a lightning flash to earth is probably about half as great again as had hitherto been believed, the potential of the thundercloud base is probably only a few per cent of previous estimates[2]. It already appears[1] that the condition for the occurrence of a flash is not that the breakdown potential be attained over the whole intervening space[2,3], but that a concentration of field should occur of sufficient intensity to initiate what may be called a 'self-propagating' discharge in a field which elsewhere may only reach a few hundred volts per cm. The implications of this are so important in the theory of discharges in general that further confirmation is very desirable. The purpose of this note is to suggest a mechanism to account for the 'darts' of the first leader stroke and the low overall voltage, to direct attention to a characteristic of such discharges which has hitherto been overlooked, and to suggest the condition under which spark breakdown occurs.

One characteristic of the first leader stroke which is nearly always observed is its discontinuous or 'dart'-like appearance[4], which in my opinion has not so far been satisfactorily accounted for. The explanation now proposed is that the *'darts' represent the sudden transition of newly formed portions of the*