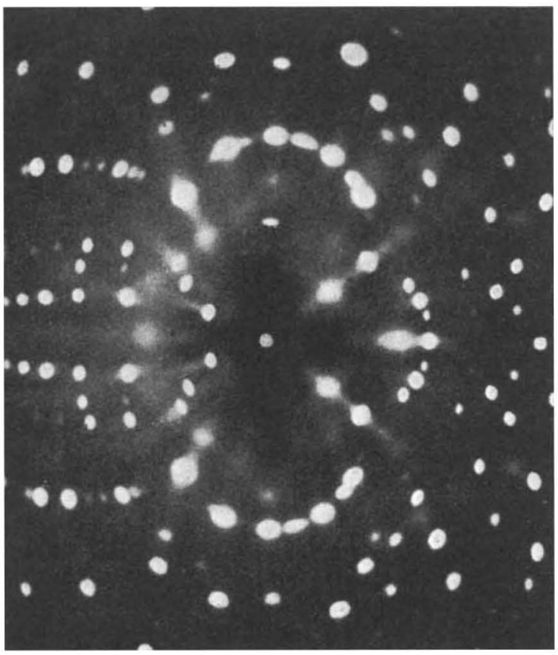
Modified Reflection of X-Rays

As stated in an earlier communication[1], quantum theory leads to the remarkable conclusion that the reflection of X-rays in crystals is of two types ; first, the classical or unmodified reflections associated with the normal structure amplitudes of the crystal ; and secondly, the quantum or modified reflections which arise when the vibrations of the crystal lattice are quantum-mechanically excited by the incident X-radiation. The direction and intensity of the reflections of the second kind have been considered theoretically in a recent paper[2]. It is shown that when the energy taken up by the crystal lattice is in the form of *acoustic waves*, the recoil of the photon is observable as *a diffuse scattering* of the incident X-radiation, while on the other hand, when the *optical vibrations of the crystal lattice* are excited, the resulting effect is *a regular reflection* of the incident radiation.



Modified reflections with calcite.

The geometric law of quantum or modified reflection, shown to be experimentally valid by an extended series of measurements[3] with sodium nitrate and with rock-salt crystals, takes the very simple symmetric form $2d \sin \frac{1}{2}(\theta + \varphi) = n\lambda$, where d is a crystal spacing, and θ, φ are the glancing angles of incidence and reflection with respect to such spacing. The formula leads to the interesting conclusion that the angle between the incident and reflected rays is independent of the setting of the crystal though, as shown both by theory and experiment, the intensity of the reflection does depend on such setting.

Table I. 400 Modified Reflections observed with a Rock-Salt Crystal. $\lambda = 0{\cdot}708$ A., $d = 2{\cdot}814$ A.

θ	φ	$\theta + \varphi$	d (calculated) Symmetric formula	d (calculated) Asymmetric formula
9° 40′	19° 18′	28° 58′	2·83 A.	2·76 A.
11° 36′	17° 26′	29° 2′	2·82 ,,	2·78 ,,
17° 46′	11° 22′	29° 8′	2·82 ,,	2·85 ,,
19° 21′	9° 57′	29° 18′	2·80 ,,	2·85 ,,
25° 21′	3° 57′	29° 18′	2·80 ,,	2·89 ,,

Table 1 (fourth column) gives the spacings calculated by the stated formula from observations on the second-order modified reflections from the cleavage planes of a rock-salt crystal, and shows fair agreement with the known crystal spacing. It is given here especially to exhibit the fact that there is no such agreement between the actual crystal spacing and the values entered in the fifth column, which have been calculated from the formula :

$$d(\sin \theta + \cos \theta \tan \varphi) = n\lambda.$$

In the latter formula, φ indicates, according to Faxen[4] and to Zachariasen[5], the direction of maximum intensity in the diffuse thermal scattering of X-rays by a cubic crystal.

The well-defined character of the quantum reflections given by an ideal crystal is illustrated in the accompanying reproduction, which is a strongly exposed Laue pattern of calcite. It exhibits the modified reflections by numerous planes in the crystal including, especially, the first, second and third order reflections from the cleavage planes, the K_α and K_β spots being clearly separated.

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[2] Raman and Nath, *Proc. Ind. Acad.*, **12**, 83 (1940).
[3] Raman and Nilakantan, *Proc. Ind. Acad.*, **11**, 398, and **12**, 141 (1940).
[4] Faxen, *Z. Phys.*, **17**, 277 (1923).
[5] Zachariasen, *Phys. Rev.*, **57**, 597 (1940).

Atomic Energy Values of Ionized Tellurium (Te II)

The identification of the structure of the spectrum of singly ionized tellurium, briefly reported by one of us previously[1], has led to the following absolute values of the characteristic terms :

$5p$	$^4S_{1\frac{1}{2}}$	= 173801	$6s$	$^2P_{1\frac{1}{2}}$	= 85375·8
	$^2D_{1\frac{1}{2}}$	= 163580	$6p$	$^4D_{\frac{1}{2}}$	= 74458·6
	$^2D_{2\frac{1}{2}}$	= 160847		$^4D_{1\frac{1}{2}}$	= 72811·2
	$^2P_{\frac{1}{2}}$	= 152281		$^4D_{2\frac{1}{2}}$	= 66515·4
	$^2P_{1\frac{1}{2}}$	= 148101		$^4P_{\frac{1}{2}}$	= 77008·9
$6s$	$^4P_{\frac{1}{2}}$	= 95352·6		$^4P_{1\frac{1}{2}}$	= 74376·0
	$^4P_{1\frac{1}{2}}$	= 91057·5		$^4P_{2\frac{1}{2}}$	= 70364·6
	$^4P_{2\frac{1}{2}}$	= 87704·4		$^4S_{1\frac{1}{2}}$	= 65461·6
	$^2D_{1\frac{1}{2}}$	= 78944		$^2P_{\frac{1}{2}}$	= 73362·4
	a	= 71559		$^2P_{1\frac{1}{2}}$	= 68150·4
	β	= 83810		$^2D_{1\frac{1}{2}}$	= 71733·8
$6s$	$^2P_{\frac{1}{2}}$	= 89246·1			

The ionization potential of Te II, as determined from the largest term $5p\ ^4S_{1\frac{1}{2}} = 173801$ cm.$^{-1}$, is 21·5 volts approximately. The detailed results will be published elsewhere.

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[1] Nature, **143**, 376 (1939).