SCATTERING OF LIGHT IN SINGLE CRYSTALS

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1. Introduction

R. J. Strutt[1] was the first to investigate experimentally the classical scattering in solids. He found that the intensities of the scattered beam in dust-free air, clear quartz and glass were in the ratio 1 : 8 : 300. C. V. Raman,[2] using the formula of Einstein and Smoluchwoski, calculated the intensities of scattering in dust-free air, clear quartz and rock salt and found them to be in the ratio 1 : 10 : 40, a result which is in agreement with the observations of Strutt. Landsberg, Mandelstam and Leontowitsch[3] found that the intensity of scattering in crystals varies linearly with temperature. The same authors[4] observed the intensity of scattering in quartz to be 2·76 times that in carbon dioxide gas and 1·43 times that in rock salt. Schæfer, Matossi and Aderhold,[5] using a photographic method, obtained a value for the intensity of scattering in calcite which is nearly twice that in quartz.

While the data available in respect of the scattering of light in solids are thus meagre, no one seems to have as yet attempted an investigation of the directional effects in single crystals. In this paper are described the results of such a study in properly cut and polished cubes of quartz and calcite.

2. Experimental Technique and Results

One-inch cubes of calcite and quartz, cut with one of the edges parallel to the optic axis in each case and polished on all sides, have been used in the present investigation. A graded set of secondary standards and the rotating sector method have been employed for obtaining the figures relating to the intensity of scattering. A suitable blue glass has been permanently introduced in front of the observation windows so as to filter off red fluorescent light, prominently present in calcite. Results obtained in respect of the intensities in calcite and quartz and the depolarisation factors in calcite alone are given below. The depolarisation of scattered light in quartz has not been measured on account of its optical activity. Elaborate arrangements for eliminating parasitic and reflected light have been made and the observations have been corrected for the convergence of the incident beam consisting of sunlight filtered through a glass cell containing cold

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water. OX, OY and OZ are mutually perpendicular and respectively represent the directions of incidence, scattering and the vertical.

TABLE I

Scattering of Light in Calcite and Quartz

(Intensity of scattering in dust-free air = 1)

Optic axis parallel to	Calcite		Quartz
	Intensity	Depolarisation	Intensity
		%	
OX	12·6	12·8	11·9
OY	11·1	11·1	9·9
OZ	14·1	7·6	8·9

3. Discussion of Results

The observed intensity of scattering in quartz is in satisfactory agreement with the values obtained by Strutt and Raman. According to Matossi's recent work,[6] one should expect the intensity of scattering in calcite and quartz to be nearly the same but he found a value for calcite which is about twice that obtained in quartz. This is probably due to the presence of un-eliminated fluorescence. The results of this investigation, however, show that the intensity is of the same order in both these cases. As regards the directional scattering, which is the most important aspect of this investigation, the observed relative intensities for the three orientations are very significant. It is interesting to note that the intensity for a particular orientation, *i.e.*, when the optic axis is parallel to OZ and therefore normal to the plane of incidence and observation, is a minimum in the case of quartz while it is a maximum in the case of calcite. Matossi developed a theory for rhombic, hexagonal, tetragonal and trigonal crystals from a knowledge of the elastic and optical constants. According to this theory, the intensities of scattering for different orientations in the case of quartz and calcite are given below. The figures have only a relative significance when compared with those given in Table I.

TABLE II

(Theoretical Results of Matossi)

Optic axis parallel to	Calcite	Quartz
OX	62·2	149
OY	61·8	124
OZ	93·1	95·7

That, when the optic axis is parallel to OZ, the intensity of scattering should be a minimum in quartz while it should be a maximum in calcite is a conspicuous result of Matossi's theory and is borne out by the experimental facts found in the present investigation. The rest of the results obtained are only in qualitative agreement with those predicted by the theory. In the case of calcite, the degree of depolarisation found by the earlier investigators is about 70% but this high value is undoubtedly due to the presence of a large percentage of unpolarised fluorescent light. One other important theoretical deduction as developed by Matossi is that under certain circumstances, the elastic constants of a crystal may exhibit a lower degree of symmetry than the optical constants and give rise to an 'anisotropic' effect. Since the density variations in a crystal are chiefly determined by the elastic constants, it is to be expected that the Rayleigh scattered radiation brought about by density variations has also a lower symmetry than other direct optical phenomena. The theory, in fact, shows that for crystals of the rhombohedral system the directions perpendicular to the optic axis are no longer equivalent to one another in scattering. This 'anisotropic' effect anticipated in theory is evident in the experimental observations. It may also be mentioned here that while the intensity of Rayleigh scattering in calcite is a maximum when the optic axis is along OZ, the intensity of the total symmetric Raman line at 1084 is a minimum for the same position of the crystal.[7]

4. Summary

Intensity and depolarisation measurements of Rayleigh scattering have been made in cut and polished single crystals of calcite and quartz, with special reference to directional excitation. Results, with the intensity in dust-free air as standard, have been given. There is qualitative agreement between the theoretical conclusions of Matossi and the observations reported in this paper. Special precautions have been taken to eliminate the effect of fluorescence and parasitic light.

REFERENCES

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