

The Polarization of Luminescence of Ruby

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THE state of polarization of the two intense red lines ($\lambda 6927$ and 6947) emitted by ruby when optically excited has been investigated. I used a single crystal of synthetic ruby, cut parallel to the optic axis. This was mounted in a glass cell filled with a liquid of nearly the same refractive index as the crystal. The ruby was excited by a narrow beam of light, suitably filtered and the luminescent light was analyzed in the transverse direction.

With the optic axis of the crystal along the vertical, say along OZ , and denoting the direction of incident light by OY , and that of observation by OX , all being mutually perpendicular, I found that the red luminescence is very strongly polarized, as much as 95 percent of the intensity being due to the vibration along OY , i.e., along the direction perpendicular to the optic axis. The intensity of luminescence due to vibration along OZ , the optic axis, is extremely feeble. When the crystal is mounted so that the optic axis was along OX , i.e., parallel to the direction of observation, the intensity of luminescence due to both the vibrations, OZ and OY , is the same, both these directions being perpendicular to the optic axis. Thus it is found that the direction of vibration in nearly the whole of the red emission is confined to one definite plane in the crystal, perpendicular to the optic axis. There is no preferred direction of vibration within this plane.

The crystal of ruby is dichroic. It has a well defined absorption band (from about $\lambda 5300$ – 5800) in the green-yellow region, when the incident light is plane-polarized with the direction of vibration perpendicular to the optic axis. There is no such absorption band shown when the direction of vibration in the incident light is parallel to the optic axis. Also there is no selective absorption noticeable for the red region. It thus appears that the process of absorption as well as of luminescence is confined to the same definite plane in the crystal—the plane perpendicular to the optic axis. Also these two processes are definitely related. For, with the exciting light plane-polarized the intensity of red luminescence is greatest when the optic axis is so oriented that the crystal has the strongest absorption for the green-yellow region.

In my previous contributions to the subject,^{1,2} I have shown that the fluorescent chromium ion Cr^{+++} , in ruby which emits the sharp red lines, must be replacing in random locations the aluminum ions of the mother-lattice—of corundum, Al_2O_3 . In this picture of the structure of ruby, the chromium ions which enter the corundum lattice as impurity become regular components of the lattice, being all situated along the optic axis which is the symmetry axis of the crystal. It is also shown from magnetic considerations that the L vectors of the fluorescent chromium ions must have the same fixed direction in the crystal. If this fixed direction is the optic axis, the orbital moment in all the ions would be along this direction and the electronic orbits would lie in the plane perpendicular to the optic axis. The processes of absorption and emission

of light by the chromium ion would then naturally be confined to this orbital plane. The observations reported above, namely, the red luminescence being all due to vibrations in one plane of the crystal and also its dichroism are well explained on this hypothesis.

I am at present engaged in investigating other bands of ruby from this point of view and also the scattering of light in the crystal and its dichroism.

¹ B. V. Thosar, Phys. Rev. **54**, 233L (1938).

² B. V. Thosar, Phil. Mag. **26**, 878 (1938).

Absorption Coefficient of β -Rays

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MANY authors¹⁻³ have shown that the absorption of natural heterogeneous β -rays is really not exponential. They are usually more absorbable for large thickness of absorbers. Thus the mass absorption coefficient of UX_2 as measured by certain experimenters varied from a minimum⁴ of $\mu/\rho=4.1$ (in Al absorbers) to a maximum⁵ of the generally accepted value of $\mu/\rho=6.7$. It is thought that this discrepancy is possibly due to the fact that the absorption curve is not exponential, so that when the measurement was made at different thickness of the absorber, it gave different values of μ/ρ .

We have measured the complete absorption curve of UX_2 from only a few mg/cm^2 to the ultimate range of UX_2 . It is definitely established that its entire logarithmic curve is not exactly a straight line, but can be well defined as a broken line composed of four to five segments (according to the conditions of measurement as shown below) of straight lines. (See Fig. 1.) The slope of each segment represents a definite value of absorption coefficient for a certain range of absorber thickness.

The intersection of the segments usually occurs at definite points corresponding to definite values of screen thickness, no matter what the measuring condition might be, but the slopes of the separate segments are not in-

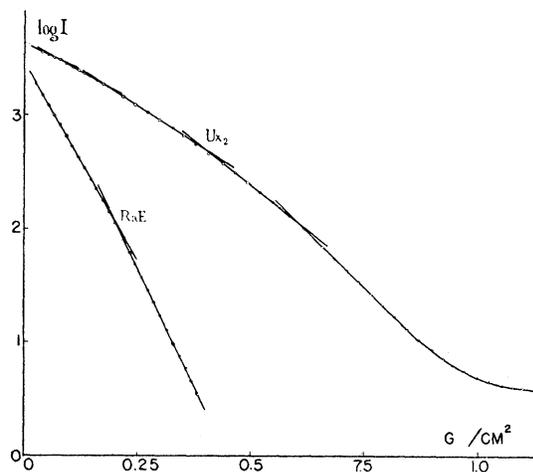


FIG. 1. Absorption of β -rays in aluminum.

TABLE I. Values of μ/ρ .

Source	Absorb- ing Screen	Range (mg/cm ²)	0	116	300	460	600	limit of β -ray
UX ₂	Celluloid	μ/ρ	3.6	5.3	6.6	8.2	10.1	
UX ₂	Al	Range (mg/cm ²)	0	70	160	385	610	limit of β -ray
UX ₂	Cu	μ/ρ	4.2	4.8	6.0	7.4	8.9	
		Range (mg/cm ²)	0	75	230	470	limit of β -ray	
RaE	Celluloid	μ/ρ	3.1	6.3	7.4	9.2		
		Range (mg/cm ²)	0	170	limit of β -ray			
RaE	Al	μ/ρ	16.6	19.7				
		Range (mg/cm ²)	0	200	limit of β -ray			
RaE	Cu	μ/ρ	16	19.4				
		Range (mg/cm ²)	0	limit of β -ray				
		μ/ρ	19					

different to the condition of measurement. When the absorbers are thin, the material of the disk, upon which the UX preparation is placed and which acts as a reflector of the radiations, is quite influential for the determination of μ . Disks made from heavy and thick materials give large values of μ , and lighter materials give smaller ones.

The absorption screens were placed on a cylindrical support, which on account of its simultaneous action as a canalizer, is mostly responsible for the alteration of the values of μ under various conditions. According to our experiments, the slopes of absorption curves are usually more flat, especially at large thickness of absorbers, when made with thin screen supports so that the complete logarithmic absorption curve shows only four segments; while it shows five segments with increased values of μ when made with thicker screen supports. However no indication of further increase of μ is observed if the support is thicker than 800 mg/cm². The radius and the material of the screen support have no appreciable effect on μ .

The distance between the active source and the screen (that is, the height of the screen support) and that between the former and the window of the ionization chamber, play also a considerable role in the value of μ thus determined especially when the screen is not thicker than 150 mg/cm². Low screen supports or large distances between the source and the ionization chamber often give small values of μ .

The variation of μ with measuring conditions and the resolution of the complete absorption curve into segments occur in using copper or celluloid screens as well as in using aluminum screens, but with different values. It is independent of the instrument used in measuring and of the method applied. The same phenomenon also happens when RaE is used instead of UX₂.

If a sufficiently thick ebonite disk is used to hold the source, if the screen support is 6 mm high and is thicker than 800 mg/cm², and if the preparation is about 4 cm distant from the ionization chamber, Table I shows the different values of μ/ρ of UX₂ and RaE.

It is worth while to note that the value of μ/ρ as obtained by most observers is very near to the mean value of those given above.

¹ J. A. Gray, Proc. Roy. Soc. **A87**, 487 (1912).

² Kovarik and McKeehan, Physik. Zeits. **15**, 434 (1914).

³ V. Douglas, Roy. Soc. Canada Trans. **16**, Section 3, 113 (1922).

⁴ Geiger, Trans. Faraday Soc. **5**, 505 (1910); Jungfeld, Physik. Zeits. **14**, 507 (1913).

⁵ A. F. Kovarik, Phys. Rev. [2] **3**, 150 (1914); Phys. Rev. [2] **6**, 419 (1915).

Temperature Study of X-Ray Diffraction by Diamond

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SIR C. V. Raman and Dr. P. Nilakantan have recently¹ suggested that observations on the temperature changes in the intensity of diffuse diffraction by diamond should provide a crucial test as to whether the optical or acoustical vibrations are involved in the occurrence of such diffraction in crystals generally. They also state that, in fact, the intensity of the diffuse maxima found for diamond is practically unaffected by cooling the crystal down to liquid air temperatures.

We have shown,² by experiment on a number of diamonds kindly provided by Professor W. T. Gordon, that the diffuse maxima are of two kinds. The "primary" diffuse diffraction, common to all diamonds examined, is really diffuse. It consists of a broad maximum accompanying the sharp Laue spot over an angle of incidence varying by not more than about $\pm 3^\circ$ from the Bragg angle, and it is quite strongly *temperature-sensitive* over a range of $650^\circ\text{C} \rightleftharpoons 30^\circ\text{C} \rightleftharpoons -180^\circ\text{C}$.³ This type of diffuse maximum, which increases in diffuseness as the angle of incidence diverges from the Bragg angle, corresponds to that found for all other crystalline substances examined.⁴ The "secondary" diffuse diffraction is not really diffuse at all. It consists, according to the diamond orientation, of a sharp spot overlaying the primary diffuse maximum, sometimes accompanied by well-defined streamers of uneven intensity; or of three small sharp spots surrounding the primary diffuse maximum; or of other related groups of spots and streaks. Geometrically it corresponds in reciprocal space to the existence of sharp horns of reflecting power extending out from the lattice points along cube directions. This secondary diffraction is *structure-sensitive*, in that its intensity varies markedly with the diamond used. For the strain-free, mosaic diamonds classed as of type II⁵ it is entirely absent; diamonds of type I, even if of uniform size and shape, may show it in very varying intensity. It is also temperature-sensitive (tested over the same range) but much less so than the primary diffraction. It persists over a range of angles of incidence more than three times as great as the range of primary diffuse diffraction, and the sharpness of the secondary maxima not only does not diminish but indeed increases as the angles of incidence and diffraction diverge.

It appears, from the description given by Raman and Nilakantan of the sharpness, persistence and relatively small temperature-sensitiveness of the effects observed by them, that they have only observed the secondary diffraction, and that only on a diamond or diamonds which show this secondary effect strongly. The photographs published by them⁶ indicate further that they were using a rather large slit or a large diamond or both. The best conditions for observation of the primary maxima are (1) a fine slit and small diamond (our best photographs were taken with a 0.5-mm slit and an octahedron weighing 1 mg), (2) a crystal orientation in which the primary and secondary