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	PAGE		PAGE
<i>Iridescent Crystals</i> —C. V. RAMAN AND D. KRISHNAMURTI	327	<i>Action of Diethylaminoethylphenothiazine (2987 RP, Diparcol) and Myanesin on Tone and Reflex Regulating Centres of the Nervous System</i> —M. SIRSI, M. LOUDON AND G. WERNER	333
<i>Nobel Award for Medicine, 1952</i>	330	<i>Atomic Furnace for Detection of Impurities</i>	334
<i>Theory of Earth's Inner Core</i>	330	<i>Letters to the Editor</i>	335
<i>Late Pre-Cambrian Glaciation in Central India</i> —DR. V. S. DUBEY AND M. S. CHAUDHARY	331	<i>Reviews</i>	351
<i>Scientific Spirit in Ancient India</i>	332	<i>Science Notes and News</i>	355

IRIDESCENT CRYSTALS*

LABRODORITE, opal and mother-of-pearl are examples of naturally occurring substances which exhibit a play of colours. The present article deals with a different case, namely that of potassium chlorate. That crystals of this substance occasionally form with a tabular habit displaying a spectacular type of iridescence has long been known to those engaged in the manufacture of this chemical. The phenomenon came into prominence through the writings of the famous trio of British physicists of the nineteenth century, namely, Stokes, Rayleigh and Kelvin. Stokes was the first to make a serious study of the case and was led to recognise that the iridescence had its origin in the reflection of light at twin-plane boundaries within the crystal. Rayleigh developed a mathematical theory of such reflection; he came to the conclusion that a single twinned layer was insufficient to explain the observed effects and postulated that the iridescent crystals were poly-

synthetically twinned. In his Baltimore lectures, Kelvin drew attention to the interest of the case in relation to molecular tactics within a crystal and was led to speculate on the particular circumstances which led to the repeated twinning so frequently exhibited by potassium chlorate. Later observers have published some further observations, but the general complexion of the subject was left fundamentally unchanged. The present authors were led to undertake a study of the phenomenon by reason of the fact that a large collection of the iridescent crystals was at their disposal. Many new facts have emerged from these studies and they throw a fresh light on the theoretical aspects of the case.

By far the most interesting specimens are those crystals which indicate by their optical behaviour the possession of a high degree of regularity in their polysynthetic twinning. Such crystals exhibit sharply defined monochromatic bands when white light is incident nearly normally on them and the reflected light is viewed through a spectroscope. A careful

* From the Presidential Address by Sir C. V. Raman to the annual session of the Indian Academy of Sciences at Trivandrum.

FIG. 1.

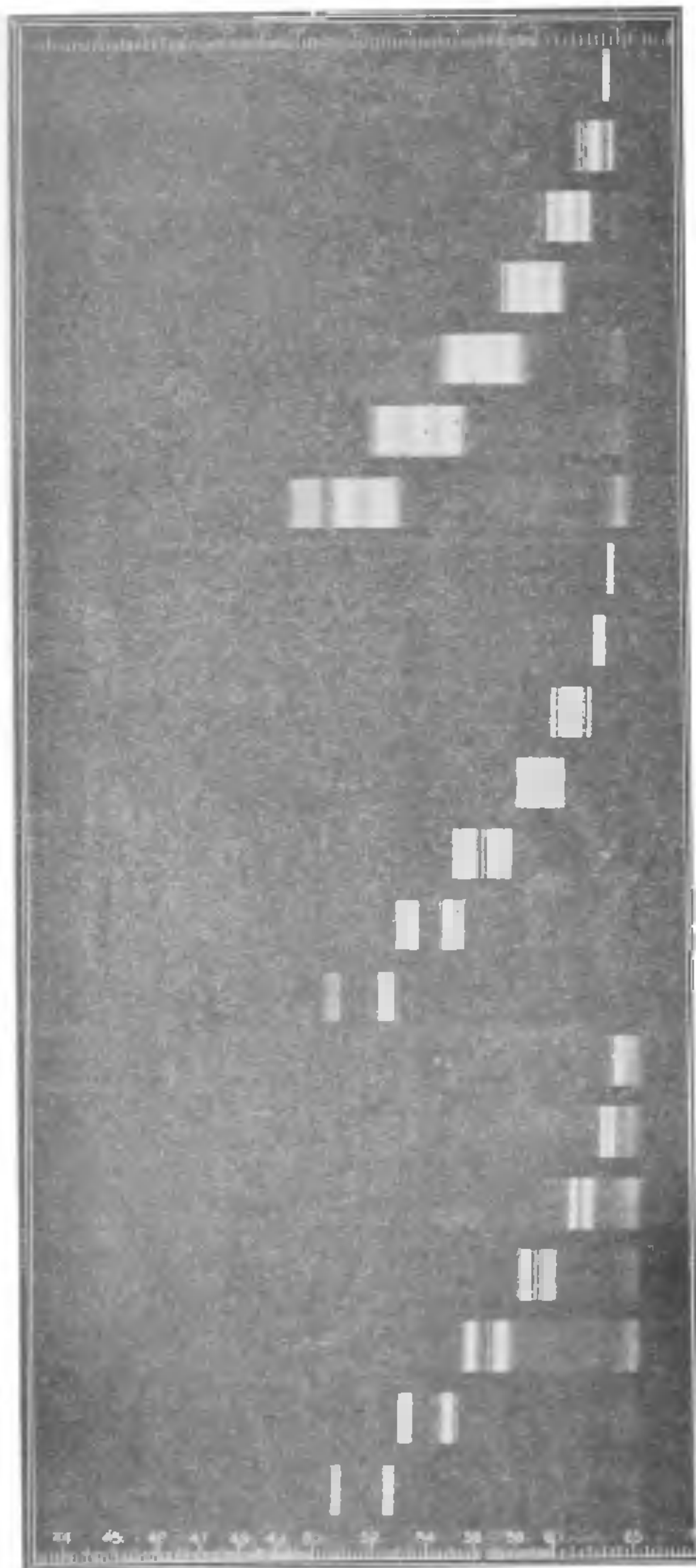
azimuth 90°

FIG. 2.

azimuth 30°

FIG. 3.

azimuth 5°



Reflection Spectra of Potassium Chlorate

study of several such crystals has brought to light the fact that the spectral character of the reflections depends in a most remarkable manner on the azimuth of the plane of incidence of the light as well as on the obliquity of such incidence. This dependence is exhibited very clearly in the sequence of spectrograms reproduced in the accompanying Figs. 1, 2 and 3. Each of these figures shows a series of seven spectra with the angle of incidence increasing by steps of 10° from 5° to 65° . The spectra recorded in Fig. 1 refer to the case in which the plane of incidence makes an angle of 90° with the particular plane in which the coloured reflections totally vanish and which is also the plane of crystallographic symmetry common to all the elements of the twinned crystal. In Fig. 2 the plane of incidence makes an angle of 30° with the latter plane, while in Fig. 3 it makes an angle of only 5° with the same.

An examination of the spectrograms reproduced shows that when the azimuthal angle is small (Fig. 3), the sharply defined *single* monochromatic reflection recorded at nearly normal incidence splits into a *doublet* the components of which drift away from each other and also towards shorter wavelengths at increasing obliquities of incidence. On the other hand, when the azimuthal angle is 90° (Fig. 1), two new components make their appearance, one on either side of the central band, and their intensity increases progressively with increasing obliquity of incidence. The three components of the *triplet* thus produced drift towards shorter wavelengths and at the same time grow more diffuse. At intermediate azimuths (Fig. 2), the reflection spectrum consists of a *quartet* of lines due to the fact that while the central component splits into a doublet which widens as in the case of small azimuths, two additional outer components also make their appearance as in the case of an azimuthal angle of 90° , though with smaller intensities than in the latter case. The whole situation may be thus summarised by the statement that the spectrum of the reflected light is, in general, a *quartet* of lines; at nearly normal incidence, the outer components are of vanishingly small intensity and the central components are an unresolved doublet, thus resulting in what appears as a *single* monochromatic reflection. When the azimuthal angle is small, the outer components have vanishingly small intensity for all incidences and the spectrum is therefore seen as a *doublet*. On the other hand, when the azimuthal angle is 90° , the outer compo-

nents have a notable intensity while the inner components are unresolved, thereby giving us a *triplet*.

Standing in the closest relation to the spectral behaviour of the reflected light are the states of polarisation of its spectral components revealed by our studies. It has been observed that both the components of the doublet reproduced in Fig. 3 are *plane-polarised* but in opposite ways. Further, and provided that the angle of incidence is not too large, the outer components of the triplet in Fig. 1 also exhibit *plane polarisation* but in a different way from the doublets appearing in Fig. 3. The central component of the triplet in Fig. 1 is however always *unpolarised*. The quartet of lines recorded in Fig. 2 exhibits in respect of the two outer components the same features of polarisation as in Fig. 1, while those of the inner components correspond to those in Fig. 3. A further interesting observation is that when the crystal is rotated in its own plane about the normal, the angle of incidence being kept constant, the two central components of the quartet approach each other and after coinciding when the azimuthal angle is 90° , separate again. The unpolarised state of the central component in Fig. 1 is thereby revealed merely as a consequence of the overlap of two components polarised in perpendicular planes.

The whole group of phenomena set forth above finds a natural explanation when we consider *firstly*, the division of an incident beam of unpolarised light into *two beams* polarised in perpendicular planes when it enters the birefringent crystal; *secondly*, the character of the reflection which each of these beams suffers when it meets the twin-plane boundaries inside it, and *thirdly*, the propagation of the beams of light thus reflected within the crystal before their final emergence from it. In general, corresponding to *each* of the two pencils into which the incident beam divides on entry, we have *two differently polarised sets* of beams reflected at the regularly-spaced twin-plane boundaries. Hence, the light emerging from the crystal consists of *four* different sets of beams the retardations suffered by which are in general different from each other. It follows that there would, in general, be four sets of sharply-defined maxima in the spectrum of the light reflected by the regular stratifications of the crystal. The reduction of the quartet of lines thus expected on theoretical grounds to a singlet, a doublet or a triplet as the case may be, depending on the azimuth and obliquity of incidence are

derivable as consequences of the special circumstances of each case. For instance, when the azimuthal angle is small, one of the two reflections in each case vanishes and the quartet reduces to a doublet. If, in addition, the angle of incidence is also small, the light paths corresponding to the two surviving sets of beams differ inappreciably and we observe a single sharply defined monochromatic band in the spectrum. *Per contra* when the azimuthal angle is 90° and the incidence is sufficiently oblique, all the four sets of reflected beams have to be

considered, but by reason of the symmetry of the case the paths for the two middle components continue to be identical and hence we observe a triplet. The explanations indicated above are completely substantiated by the observed states of polarisation of the components in each case taken in conjunction with the known characters of the birefringence of the crystal.

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NOBEL AWARD FOR MEDICINE, 1952

DR. SELMAN A. WAKSMAN, Professor of Soil Microbiology at Rutgers University, New Jersey, has been awarded the 1952 Nobel Prize for Medicine, for his discovery of streptomycin. His interest in the chemistry of living processes began many years ago in Russia—he was born in the Ukraine in 1888—and by 1915, five years after his arrival in the U.S.A., he had already undertaken a study and classification of the actinomycetes. His investigations were mainly agricultural until 1939, when Rene Dubos, who had been one of Waksman's students at Rutgers University, isolated from a spore-bearing soil bacterium, a substance (gramicidin) which appeared to be capable of destroying pathogenic bacteria. About this time also Gleming's discovery of the anti-bacterial action of penicillin was being developed for therapeutic purposes, and Waksman turned his full attention to an attempt to isolate from the soil micro-organisms possessing anti-biotic properties. It was early in 1944 that with Schatz and Bugie he announced the isolation from *Streptomyces griseus* of streptomycin, a

substance antagonistic to both gram-negative and gram-positive bacteria including *Mycobacterium tuberculosis*. The fact that streptomycin was the first effective anti-biotic to be used in the treatment of tuberculosis has become a part of medical history. One of its most notable successes has been in tuberculous meningitis, no longer an invariably fatal disease.

Streptomycin has well-known limitations, among them its toxic effect on the eighth nerve and the development of resistance by tuberculosis bacilli. In reviewing the possibility of further advances in this field, Dr. Waksman wrote in the *British Medical Journal* two years ago: "Sooner or later other anti-biotics will be found which are more effective than either (streptomycin and neomycin) and less toxic. The fact that in the various surveys on anti-biotic production by micro-organisms the acid-fast bacteria are found to be among the most sensitive forms points to the possibility of the existence of such agents. Finding these is merely a matter of further search".

(—By courtesy of the *British Medical Journal*)

THEORY OF EARTH'S INNER CORE

FOR some years it has been known that the earth contains a central core with a radius of 2,200 miles. This central core is physically distinct from the outer mantle, which extends up the further 1,800 miles to the earth's surface. Several distinct lines of evidence have pointed to the bulk of this central core being in a fluid state. Over the years from 1935 to 1939, it was concluded that the central core contained an inner core with a radius of about 800 miles. Professor Bullen, Professor of Mathematics at Sydney University, Australia,

has recently adduced some evidence to the effect that while the outer part of the central core is fluid, the inner core is solid, with a density of about 18 times that of water. There is some division of opinion on the question of the composition of the outer part of the central core, but his work favours the view that the central core consists of a high density liquid form of silicate rock with a density about 11 times that of water, and that the inner core is chemically distinct and consists of iron, nickel and probably some denser metals,