

At the suggestion of Dr. R. H. S. Thompson, these tests were repeated on rat skin, using much smaller quantities of mustard gas (for example, 1 drop of a 5 per cent solution in ethanol, an amount known to be just sufficient to produce oedema, and to interfere with enzymic activity of the skin): under these conditions, apparently normal yields of nucleoprotein were obtained from the treated skin (any precipitation that may have occurred being too small to be detected by the semi-quantitative method of comparison used).

Effect of other compounds on nucleoprotein: This investigation, forming part of a separate study, gave results of interest in connexion with the present work, and may be summarized as follows: similar precipitation of nucleoprotein was obtained with a few compounds closely related chemically to mustard gas, all possessing strong vesicant action. On the other hand, lewisite gave no precipitation. In the case of $\beta\beta'$ -dichlorodithiethylsulphone and of divinylsulphone, no actual precipitation occurred, but the precipitate formed on acidification (subsequent to the treatment with these compounds) failed to re-dissolve on addition of alkali. (These last results need confirmation on other samples of nucleoprotein.)

Dichlorodimethylsulphide (an analogue of mustard gas, almost non-vesicant, but hydrolysing rapidly in water), also *t*-butyl chloride, and other related compounds, produced no precipitate when shaken with nucleoproteins.

Though conclusions from *in vitro* tests with purified proteins must be accepted with caution, since the 'purification' may have contributed towards the effects produced, the observation that nucleoproteins are rapidly precipitated by mustard gas is rendered significant by the fact that after treatment of skin with mustard gas *in vivo*, no soluble nucleoprotein is any longer extractable. The formation of an insoluble nucleoprotein-mustard gas compound cannot, therefore, be attributed to the use of partially denatured nucleoprotein, but represents a product of interaction which bears some relation to the action of mustard gas on living cells.

As evidence that mustard gas can combine with proteins, these findings support the previous results from immunological studies⁷, and are in keeping with the more recent results with corneal collagen⁹, keratein¹⁰, various proteins, using mustard gas with radioactive sulphur as tracer¹¹, egg albumin, casein, and amino-acids¹². (Reference should also be made to the observed interaction between 'nitrogen mustards' and sodium thymonucleate, etc.¹³)

However, unlike the compounds formed by mustard gas with other proteins, that formed with nucleoprotein is highly insoluble. Such specific precipitation *in vivo* may produce special effects, for in failing to precipitate cytoplasmic proteins, mustard gas might be able to penetrate the nucleus and produce characteristic changes there. In this connexion, it may be noted (*a*) that the lethal effect of mustard gas on cells is delayed for several hours, as with X-rays, but unlike most other irritants, and (*b*) that mustard gas also behaves like X-rays in producing mutations in *Drosophila melanogaster*, while other irritants (including lewisite) do not¹⁴.

Intra-nuclear precipitation of nucleoproteins could only represent one aspect of the biological action of mustard gas. Apart from the cytoplasmic nucleoproteins, associated with mitochondria, microsomes, etc., there are enzymes of nucleoprotein type (for

example, the flavoproteins) in the cytoplasm, precipitation of which would seriously interfere with function. Furthermore, combination of proteins (or other important cell constituents) with mustard gas, *without precipitation*, would also lead to important changes in living cells.

Recent evidence points to a multiple mechanism of vesicant action, and the present results lend further support to this view. Some of the local effects are more likely to be associated with interference with enzyme action in the cell¹⁵, while the hypersensitivity which may develop after repeated exposure is more readily explained on the development of antigenically changed proteins⁷. Nevertheless, in view of the important role which nucleoproteins have in the living cell, their irreversible precipitation *in vivo* is likely to have serious consequences, and may well be largely responsible for the necrotizing effects in mustard gas burns.

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¹ Clarke, *J. Chem. Soc.*, **101**, 1533 (1912).

² Cashmore and McCombie, *J. Chem. Soc.*, **123**, 2884 (1923).

³ Lawson and Reid, *J. Amer. Chem. Soc.*, **47**, 2821 (1925).

⁴ Jany and Sella, *Biochem. Z.*, **275**, 234 (1935).

⁵ Berenblum, Kendal and Orr, *Biochem. J.*, **30**, 709 (1936).

⁶ Peters, *Nature*, **138**, 327 (1936).

⁷ Berenblum and Wormal, *Biochem. J.*, **33**, 75 (1939).

⁸ Ogston, Holiday, Philipot and Stocken, Report to Ministry of Supply (1941).

⁹ Pirie, Report to Ministry of Supply (1941).

¹⁰ Peters and Wakelin, Report to Ministry of Supply (1941).

¹¹ Banks, Bournsnel, Francis, Hopwood and Wormal, *Biochem. J.*, **40**, 745 (1946).

¹² Hartwell, *J. Nat. Cancer Inst.*, **6**, 319 (1946).

¹³ Gjessing and Chanutin, *Cancer Res.*, **6**, 593 (1946).

¹⁴ Auerbach and Robson, *Nature*, **157**, 302 (1946).

¹⁵ Dixon and Needham, *Nature*, **158**, 432 (1946).

STRUCTURE AND PROPERTIES OF DIAMOND

THE diamond offers a variety of fascinating problems to the research worker interested in the correlation of physical properties with crystal structure, and the well-known variations of crystalline habit, colour, fluorescence, and so forth, are responsible for a bulky scientific literature. Its scientific interest and its beauty as a gem inspired many abortive attempts at synthesis, and probably one successful solution of the problem¹. It is not surprising that the diamond was among the very first crystals examined by X-ray methods, and the essential simplicity of the structure is in striking contrast with the complexity revealed by a detailed examination of the crystalline form and properties.

The researches of Robertson, Fox, and Martin, published in 1934², established firmly the existence of two kinds of diamond, known as Type I and Type II for lack of clear understanding of the origin of the observed differences in various physical properties. Since that time, much experimental data has been obtained by X-ray methods in the Davy

Faraday Laboratory, London, and it is now at least possible to show in what respects the X-ray diffraction effects characteristic of diamonds of Types I and II are *not* explicable in terms of theories which cover phenomena observed with other crystals. A very large amount of interesting experimental work has also been reported in publications from the Indian Institute of Science at Bangalore, especially in two symposia^{3,4} on the "Structure and Properties of Diamond". The team at Bangalore, under the direction of Sir C. V. Raman, originally directed attention to anomalies in X-ray scattering, and has more recently applied a variety of physical methods to the examination of a very fine collection of diamonds. The earlier work (particularly that on diffuse X-ray reflexions) served as the basis for the development, by Raman⁵, of a general theory of the dynamics of the crystal lattice which has been strongly criticized by theoretical and experimental workers⁶ and has not found acceptance in other laboratories than that at Bangalore. Later, in order to provide a structural interpretation of experimentally observed variations in physical properties and growth habit, Raman⁵ advanced a theory of the symmetry of diamond which implies the existence of four different crystal structures. Raman's exposition and development of this theory were much less obscure than in the case of the general theory of the crystal lattice, but its application to X-ray diffraction effects has been criticized very severely⁷, and again it must be admitted that acceptance is withheld, outside the Bangalore laboratory.

It is against this background that the second symposium on the structure and properties of diamond⁴, here under review, must be judged. The style and general content of the twenty-one papers, all contributed by Raman and his collaborators in the Bangalore Institute, show no serious departure from those of previous publications from this school of research; the treatment is in many cases descriptive rather than analytic, and, in the reviewer's opinion, the value of the observational data is reduced rather than enhanced by the insistence with which they are adduced in support of the Raman theories, and stated to be in flat opposition to others. This treatment succeeds only in conveying the impression, whether rightly or wrongly, that the Raman theories dominate the experimental researches of the Bangalore school to an extent which must encourage an uncritical acceptance of interpretations favouring Raman's views, while adverse criticisms of the Raman theories, expressed by other workers in this field of research, remain unrefuted. In the review which follows, therefore, no attempt is made to assess the theoretical significance of the new experimental data.

Crystalline Form and Microscopic Structure

In the first of four papers on topics which may be grouped under this heading, Raman and Ramaseshan (pp. 1-24) develop the idea that the curved faces and edges which frequently occur in natural diamonds are not accidental features of growth, as is commonly supposed, but represent essential properties of the crystal. On this view the curved faces appear as a direct consequence of the act of solidification from a drop of liquid carbon, while the edge-development gives the clue to the true internal symmetry of the structure; the majority of the seventy-two diamonds examined are classified, in this way, as showing

tetrahedral symmetry, though truly octahedral symmetry is established in some cases and interpenetration of positive and negative tetrahedral forms is frequent. A semi-quantitative elaboration, by Ramaseshan (pp. 122-129), of the suggestion that curvature of the faces corresponds directly with curvature of the liquid drop of carbon, requires the *ad hoc* assumption that a high degree of directed valency-bonding exists before solidification. The calculations of crystal surface energies are correlated with cleavages in another paper by Ramaseshan (pp. 114-121); but it is perhaps not unreasonable to suggest that these calculations, and the deductions drawn from them, may represent an over-simplification of the very complex energy problems associated with crystal growth and face-development under conditions and in an environment of which little or nothing is known. For their bearing on these views as to the significance of curved faces and edges, the recent experimental observations of Tolansky and Wilcock⁸ are of great interest; it seems that the multiple-beam interference technique establishes beyond any reasonable doubt that these features of the topography of the diamond are due to the deposition of a succession of stepped growth-sheets—a mode of crystal growth commonly observed in other substances.

A paper by Ramachandran (pp. 65-80) describes in detail the dimensions, orientation, and optical characteristics of the laminated structures seen under optimum conditions in many diamonds of Types I and II, and attributes the positive and negative uniaxial characters of the laminae to states of compression and tension arising from variations in lattice-spacing in the different kinds of diamond structure postulated by the Raman theory. The real existence of such variations in spacing, reported by R. S. Krishnan³, has, however, been denied by Lonsdale⁷, so that the validity of Ramachandran's interpretation of his observations is open to question.

X-Ray Studies

Studies by R. S. Krishnan (pp. 33-44) and by Ramachandran (pp. 95-103) represent the extension and refinement of researches already reported, the former on the temperature-variation of lattice-parameter, the latter on X-ray topography, with an attempt to correlate variations in X-ray reflecting power with the laminations observed optically and with luminescence phenomena.

In a theoretical study, Ramachandran (pp. 58-64) calculates the X-ray diffraction effects to be expected for a diamond structure in which carbon atoms occupy the sites 000, $\frac{1}{4}\frac{1}{4}\frac{1}{4}$ in the cubic unit cell, but are assumed to have non-spherically symmetrical electronic configurations. He concludes that it is impossible from the presence or absence of the (200) and (222) reflexions to decide uniquely whether the symmetry of the crystal is tetrahedral or octahedral. He states, however, that "the (222) reflection is . . . absent only in the fully antisymmetric case", which (if the reviewer has understood Ramachandran's nomenclature correctly) is equivalent to saying that the (222) reflexion is absent only when the two carbon atoms at 000, $\frac{1}{4}\frac{1}{4}\frac{1}{4}$ are identical and have identical orientations, a requirement of the tetrahedral structure. Lonsdale⁷ has shown that a real (222) reflexion exists, which would appear, on Ramachandran's own calculations, to prove that the symmetry is octahedral.

Atomic and Electronic Vibrations

The greater part of the symposium is devoted to the observation of optical properties and their interpretation in terms of atomic and electronic vibrations.

Precision measurements are included in six papers, of which two by Krishnan (R. S.) (pp. 25-32 and 45-57) report observations of the second-order Raman spectrum and its variation over a wide range of temperature. Ten distinct second-order lines have frequencies corresponding with infra-red absorption maxima, and five of them are octaves of the frequencies assigned in the Raman theory to lattice vibrations. It is difficult to attach any real significance to the proposed interpretation of the Raman spectra, when Krishnan persists in associating the octave of the fundamental Raman frequency 1332 cm^{-1} with the steepest point in the curved line joining an infra-red absorption maximum with the adjacent minimum—an arbitrary proceeding already condemned by Sutherland⁹. On the purely experimental side, however, it is to be noted that a recent communication in *Nature*¹⁰ by Krishnan reports the complete resolution of the Raman lines, which in the symposium appear only as minute 'steps' on a continuous faint background.

Four papers by Ramanathan (pp. 130-161) describe infra-red, visible, and ultra-violet absorption properties of a large number of diamonds, and demonstrate that it is not possible to draw a definite line of demarcation between Type I and Type II diamonds from observations on infra-red absorption near 8μ and ultra-violet absorption near 2250 \AA .

Descriptive accounts of the luminescence exhibited by diamonds under various stimuli occupy no fewer than five papers, and Ramachandran (pp. 81-94) outlines a semi-quantitative theory of the luminescence due to X-ray excitation. In a short review it is possible to do no more than indicate some of the effects described and discussed in papers by Rendall (pp. 168-175), Chandrasekharan (pp. 182-197), Ramachandran and Chandrasekharan (pp. 176-181); they include the blue and yellow fluorescence patterns, phosphorescence which persists for a short time after cutting off the exciting radiation, thermoluminescence observed on heating to 270° C ., and the deactivation effect of radiation of wave-length longer than 4200 \AA ., which causes a 'flash' emission of visible light. In the last of the papers listed above, Ramachandran and Chandrasekharan bring some evidence in support of their suggestion that luminescence effects are due to 'forbidden' electronic transitions.

Conclusion

The symposium includes also papers by Ramaseshan (pp. 104-113) on the Faraday effect and by Achyuthan (pp. 162-167) on photoconductivity, both largely experimental.

Many of the experimental data recorded in this substantial volume of about 200 pages, illustrated by many plates and drawings, are of great interest, actual or potential. The attempted interpretation of these data, however, in terms of the Raman theories, cannot be convincing unless the criticisms already made by workers outside the Bangalore Institute are answered in full and in such a way as to satisfy the critics. Instead, the Bangalore workers would sometimes seem to turn to fresh experimental approaches in the search for further support for their theories, leaving the original criticisms unanswered. The

inevitable result is that full recognition is withheld from what is obviously an enthusiastic and hard-working research team, engaged on a problem of great interest and importance.

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¹ Bannister, F. A., and Lonsdale, K., *Nature*, 151, 334 (1943).

² Robertson, R., Fox, J. J., and Martin, A. E., *Phil. Trans. Roy. Soc. A*, 232, 463 (1934).

³ (First Symposium) *Proc. Indian Acad. Sci.*, 19, A, 139 (1944).

See also Preston, G. D., *Nature*, 155, 69 (1945).

⁴ (Second Symposium) *Proc. Indian Acad. Sci.*, 24, A, 1 (1946).

⁵ Symposium on the Quantum Theory of X-Ray Reflection, etc., *Proc. Indian Acad. Sci.*, 14, 317 (1941).

⁶ See, for example, Born, M., Lonsdale, K., and Smith, H., *Nature*, 149, 402 (1942).

⁷ Lonsdale, K., *Nature*, 155, 144 (1945).

⁸ Tolansky, S., and Wilcock, W. L., *Nature*, 157, 583 (1946).

⁹ Krishnan, R. S., and Ramanathan, K. G.; and Sutherland, G. B. B. M., *Nature*, 157, 45, 582 (1946).

¹⁰ Krishnan, R. S., *Nature*, 159, 60 (1947).

OBITUARIES

Sir Almroth Wright, K.B.E., C.B., F.R.S.

ALMROTH EDWARD WRIGHT was born in Yorkshire in 1861, the second son of the Rev. C. H. H. Wright, a distinguished Ulster divine, by his wife Ebba, daughter of Nils Almroth, governor of the Swedish Royal Mint. He was educated at first in Germany and France and then privately in Belfast before going up to Trinity College, Dublin, where he graduated B.A. in 1882 and M.B., B.Ch. in 1883, proceeding to the M.D. degree in 1889. After working at the Universities of Leipzig, Strasburg and Marburg, he returned to England to become demonstrator in pathology in the University of Cambridge, where he took the B.A. degree in 1888. In 1889 he became demonstrator in physiology in the University of Sydney, returning three years later to become professor of pathology at the Army Medical School at Netley, where he remained until 1902.

Following up the tentative essays of Pasteur, Haffkine and Pfeiffer, Wright originated in 1896 the system of anti-typhoid inoculation. The results of this prophylactic measure in South Africa and India were so striking that before the outbreak of the First World War it had been made standard practice in the British Army. In 1898 Wright went to India as a member of the Plague Commission. In 1902, following differences with the War Office about anti-typhoid inoculation, he resigned his professorship at Netley and became pathologist to St. Mary's Hospital, London. Here he founded the Inoculation Department, of which he was the first principal. Here, too, he originated the system of therapeutic inoculation for bacterial infections (vaccine therapy) and numerous methods for measuring the protective substances in the blood, notably the opsonic index. He held also a professorship of experimental pathology in the University of London.

In 1914 Wright published the results of his investigations into the incidence, prevention and treatment of pneumonia among the natives employed in the South African mines.

During the First World War, Wright served as consulting physician to the British Forces in France, and devoted himself to studying the immunology of wound infections and to combating the ravages of gas gangrene. This was his last great research.

By 1925, all Wright's important contributions to bacteriology and immunology had been made. He worked as assiduously and devotedly as ever, but in unpropitious circumstances. All the problems sus-