Recent Crystallography*

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ALTHOUGH some of the considerations already discussed are admittedly provisional, they show how the knowledge of protein structure is steadily increasing, how, in fact, the examination of the structure can be looked on as a branch of crystallography. The X-ray methods furnish measurements of distances and angles which suggest the possible forms of the proteins in space, forms which must obey certain geometrical conditions. Some of these are carried over from examinations of other organic molecules; others are derived from direct X-ray measurements of the proteins themselves. It then becomes of great interest to connect the physical form with biological properties.

Quite recently a remarkable discovery by Dr. Stanley, of the Rockefeller Institute at Princeton, has shown that a certain virus, which causes disease in tobacco plants, is a protein. Its composition falls within the protein limits already quoted. Its molecular weight has been found by Svedberg to be of the order of 17 millions. It has reactions to polarized light which show that it is crystalline, and that the great molecule is needle-like in form. The conclusions follow from the fact that a solution of the virus shows when disturbed the effect known as 'streaming double refraction'. When minute crystals are suspended in a liquid medium they normally point in all directions. If the suspension is examined between crossed Nicol prisms, the field is dark. But if the suspension is so disturbed that the particles in any region are

like a single crystal, and illumination appears in the field. The very beautiful display of this effect by a suspension of the needle-like crystals of vanadium pentoxide has been known for some time.

Fig. 4.

X-RAY PATTERNS OF DRY GEL (A), WET GEL (B), AND 13 PER CENT SOLUTION (C).

(By courtesy of J. D. Bernal.)

Fig. 3.

WAKE OF A GOLDFISH SWIMMING IN A DILUTE SOLUTION OF PROTEIN FROM A SAP INFECTED BY TOBACCO VIRUS, OBSERVED BETWEEN CROSSED NICOLS.

(Photo by Ramsey and Muspratt.) (By courtesy of J. D. Bernal.)

arranged to point in the same direction, or at least so that on the average they point more in one direction than another, the whole behaves

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The disturbance of the liquid by stirring of any kind produces whirlpools in which layers of the liquid slide past one another in shearing motion. Any long rigid particle lying across the general direction of flow is moved forward more slowly at one end than at the other. In consequence it tends to set itself parallel to the stream. But the conditions are unstable. If it continues its rotatory motion past the position of parallelism, it undergoes a further rotation of 180° . On the whole, however, one may expect the periods of parallelism to be much longer than those in which the particle lies across the stream. This effect can be shown by allowing glycerine to move along a narrow glass tube, carrying with it short lengths of a fine fibre.

In a whirlpool, therefore, the rod-like crystalline particles tend to set themselves tangentially to the whirl. A beautiful illustration of this effect is given in Fig. 3, which is reproduced from a communication to *NATURE*², by Bernal and others. A small fish is moving in a virus suspension between crossed Nicols. The movements of the tail leave vortices behind them and the crystalline needles of the virus follow the movement of the liquid in spirals approximating to circles. The field shows bright spots arranged at the corners of a cross; because the line of movement makes an angle of 45° with the planes of the crossed Nicols at four points.

Bernal and his collaborators have been able to obtain X-ray diffraction photographs of the virus. These are shown in Fig. 4. The pure virus in a suspension stronger than 2 per cent separates into

Fig. 5.

THE CENTRAL PORTION OF A MOLECULE OF NICKEL PHTHALOCYANINE, SHOWING THE ELECTRON DENSITY OF THE NICKEL ATOM, PROJECTED ON THE PLANE OF THE DIAGRAM.

(J. M. Robertson.)

layers which are sharply distinguishable. One of these (*B*) is "an extremely soft gel well orientated and with much higher birefringence, 0.007, than the liquid. The outer part of this wet gel shrinks by 50 per cent and forms a layer of higher refractive index, but lower birefringence, 0.003". These two layers give respectively the photographs *A* and *B* of Fig. 4. Photograph *C* is obtained from a 13 per cent solution in which the crystals are orientated by flow along a narrow tube. A similar set of lines is found in the three cases, indicating a hexagonal arrangement, such as would naturally be found in an arrangement of long rods put side by side. In *A* they are at a distance, rod to rod, of 152 Å.; in *B*, 210 Å. In *C* the distance is more vaguely defined, as one would expect, and ranges from about 300 Å. to 470 Å.

Besides these evidences of regularity in the side to side placing of the molecules, there is evidence in other photographs of much narrower spacings, which do not vary with the condition of the material and the arrangement of the molecules side by side. They refer obviously to regularities within the molecule. The length of the spacing is given as $3 \times 22.2 \pm 0.2$ Å., a result in close agreement with measurements of Wyckoff and Corey on the tobacco virus and on a variety of it known as the *aucuba* virus. It is very remarkable that this virus, though a crystalline protein, appears to be capable of multiplying itself and of generating an anti-body, and to be liable to mutation.

Brief reference may be made to a few other examples of the development of crystallography

by means of the X-ray methods, supplemented now by the methods of electron diffraction.

Dr. J. M. Robertson has investigated in much detail the nickel phthalocyanine. The shadow picture contains a beautiful display of the electron distribution in the nickel atom, projected upon the plane of the diagram. The central part of the molecule containing this atom and its immediate surroundings is shown in Fig. 5. The contour lines of the nickel atom are drawn so that from line to line there is a difference of two electrons per square Angström unit. In the other part of the figure the difference is one electron per unit area. The accuracy is high, and the figure must give a fairly accurate representation of the distribution of the electrons in the nickel atom. It can be represented closely by an empirical formula of the form Ae^{-kr^2} where r is the distance from the centre of the atom.

Applications of the new crystallographic tools to the study of practical problems of metallurgy and engineering have been numerous and important. As an example may be taken the study of the effects of cyclic stress upon a mild steel, recently described by Gough and Wood³. It is well known that metal structures can in certain cases be fractured by a sufficient application of intermittent or cyclic stresses; that, to use the

Fig. 6.

X-RAY PHOTOGRAPHS TAKEN AT DIFFERENT DEPTHS IN A NITRIDED STEEL: THE FIGURES ON THE LEFT REFER TO THE HARDNESS. THE TOP FIGURE SHOWS THAT AT THE VERY SURFACE IRON NITRIDES HAVE BEEN FORMED.

(From the Report of the National Physical Laboratory, 1933, by permission of the Controller, H.M. Stationery Office.)

technical term, they become fatigued. Gough and Wood establish the important point that "the application of cycles of a safe range of stress (strain) is unable to cause *progressive* damage to the state

of the structure". The X-ray powder photographs of a piece of mild steel show no change during the imposition of cyclic stresses of 9 tons to the square inch, up to 10^7 repetitions. This is just within the safe range of stress. But when the stress is increased to 9.7 tons, which lies outside the safe range, there is a gradual change. The X-ray photographs show that the crystal grains are being broken up into powder consisting of far smaller crystal portions, and the structure fractures after about half a million cycles or so. Thus the progressive deterioration of the specimen takes place only when a certain safe load has been exceeded.

In this case the appearance of the X-ray photograph indicates the condition of the material. In a number of instances the photographs are now used in this way; the spacings of the crystal planes which are determined by the positions of the lines are not in question. Thus the series of photographs of Fig. 6 shows the conditions of a steel at various depths below the surface when ammonia at 500°C . has been passed over it. The diffuse character of the lines shows that the

crystallites have been broken up. Close to the surface the fragments are so small that the material is practically amorphous. At the surface itself iron nitrides have been formed. The physical effect is a very marked hardening, as indicated by the hardness numbers in the diagram. The whole effect is contained within a quarter of a millimetre from the surface. These photographs are due to Dr. G. Shearer, of the National Physical Laboratory.

Diffuseness in the photograph may also be caused by any distortion of the lattice, such as occurs when a specimen is severely strained. This is found to be the case, for example, in the operation of wire drawing.

One of the most remarkable developments of X-ray crystallography is the advance in our knowledge of the internal condition of an alloy. The 'order-disorder' theory, as it is termed, has been especially studied in the Manchester laboratories, and has been described by W. L. Bragg⁴.

² NATURE, 133, 1051 (1936).

³ Proc. Roy. Soc., A, 154, 510 (1936), plates IX, X.

⁴ Proc. Roy. Soc., A, 145, 699 (1934).

Obituary Notices

The Right Hon. Lord Conway

LORD CONWAY, whose death on April 18 at the age of eighty-one years will be widely regretted, was a many-sided man. He had very varied interests. He was a professor and lover of art; he was a collector of art treasures; he was a politician; and he was a mountaineer. In no one line did he achieve real greatness. But he always and everywhere derived keen enjoyment out of life and he had the knack of conveying his enjoyment to others. Everybody liked him.

Perhaps it was in mountaineering that Conway found his chief enjoyment. Among the mountains his love of beauty found an ample field. As he climbed not as an exercise in gymnastics but in order to get the real feel of the mountains from close contact with them, he was able to develop his true fundamental self among them. He climbed the Alps "from end to end". But not content with them, he ventured farther afield and travelled among the supreme mountains of the world. In the full maturity of his climbing powers, he set out for the Himalaya in search of a fairly accessible 25,000 ft. peak. He was not the first from Europe to attempt Himalayan peaks. Some forty years before him, the Schlagentweits had climbed to at least 22,000 ft. and more recently Graham had reached 23,000 ft. on Kabra. But Conway's expedition to the Karakoram Himalaya was the first to direct the attention of the world to the glory of the Himalaya. He chose as the scene of his operation what is perhaps the finest part of the

whole range—the region of the Karakoram Himalaya. For sheer sublimity of natural beauty it is unsurpassed. It lies beyond the forest-class zone of lower altitudes. Here there is nothing but bare rock and ice and purest snow. All is of sternest grandeur. There are several peaks of 24,000 ft. and 25,000 ft. in height, four of 26,000 ft., one of 27,000 ft. and supreme over all, K_2 —28,250 ft.—second only to Mount Everest itself in altitude but far nobler in aspect.

Here Conway was in his element. It was not in his nature to strive after records on climbing. Indeed, years after, he took no interest in attempts on Everest; to climb a mountain merely because it happened to be the highest in the world made no appeal to him. What really moved him in the Karakoram region was the glory of the mountains. There where even the valley bottom was higher than the summits of the Alps—there surrounded by peaks of towering grandeur—he felt his whole soul uplifted towards them. He entered into the spirit of the mountain. In his writings he tried to convey something of his own enjoyment; and he was successful. Others responded to the call. Since his time, German, Italians, and French, as well as other British have gone there too.

Conway was also a man of deep religious feeling. No such true lover of beauty, and especially of sublime mountain beauty, could help being religious. He could not help being in love with such beauty, which aroused in him such an ecstasy of delight.

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