GREAT ADVANCE IN CRYSTALLOGRAPHY.[1]

TWO pictures of the actual apparatus employed (one of which is produced in Fig. 7), and an explanatory diagram of it (Fig. 8), will enable the precise nature of the experiment to be grasped. A plate, 1 cm. square and 0.5 mm. thick, was cut from a good crystal of zinc blende parallel to a cube face, and
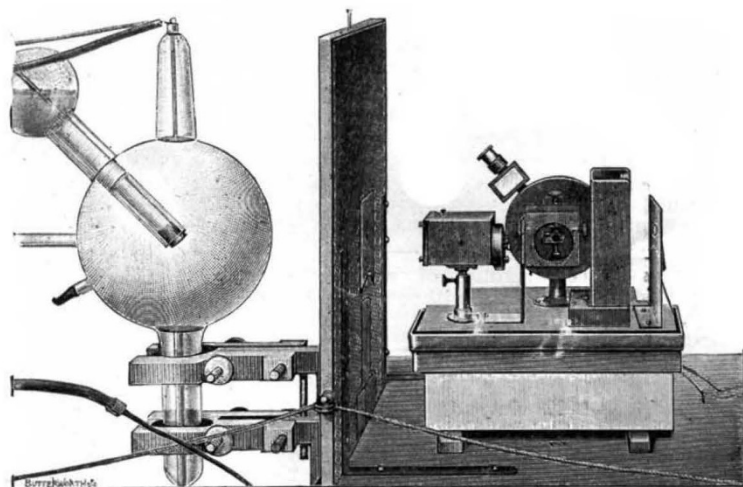

FIG. 7.—Apparatus of Friedrich, Knipping, and Laue for passing X-rays through crystals and photographing the effect.

adjusted on the crystal holder of a goniometer in the path of a very narrow pencil of X-rays from the bulb, isolated by their passage through a succession of lead screens (lead being impervious to X-rays) pierced by small holes. The last screen, which gave the final form to the pencil of rays, was a plate of lead 1 cm. thick, pierced by a cylindrical hole 0.75 mm. in diameter, and fitted with a delicate means of adjustment so that the axis of the boring could be brought
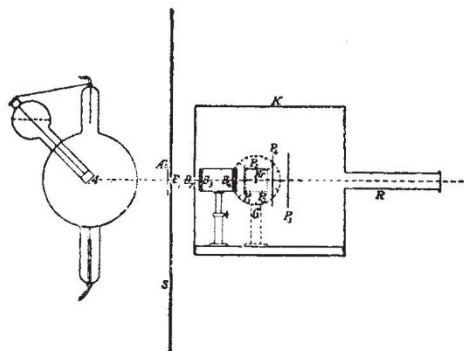

FIG. 8.—Diagrammatic representation of apparatus of Friedrich, Knipping, and Laue. A, Antikathode of X-ray bulb; B₁, B₂, B₃, B₄, diaphragms of lead; K, leaden box-screen with tubular termination R; S, large leaden screen; G, goniometer; P₁, P₂, P₃, P₄, P₅, photographic plates; Kr, Crystal; Al, aluminium plate.

exactly perpendicular to the crystal plate. The beam of pure X-rays of circular section, after passing normally through the crystal plate, was received on a Schleussner-Röntgen photographic plate, which was afterwards developed with rodinal.

The developed plate showed an intense circular spot at the centre, caused by the direct X-rays, and a con-

[1] From a discourse delivered at the Royal Institution on Friday, March 14, by Dr. A. E. H. Tutton, F.R.S. (continued from p. 494).

siderable number of other spots of elliptical shape, arranged in a geometrical pattern. Three of these original photographs are exhibited on the screen (and two are also reproduced in Figs. 9 and 10). If a series of such photographic plates be used, at different distances from the crystal (as for Figs. 9 and 10), the fact is revealed that the spots are formed by rectilinear pencils of rays spreading in all directions from the crystal, and some of them inclined more than 45° to the direction of the incident rays. These deflected beams show similar properties to the original X-rays, ionising air and helium just like the latter, and with the same degree of variation with the pressure. Hence, there can be no doubt that the character of these deflected rays issuing from the crystal is that of unaltered X-rays, and that they are due to the deflection of

FIG. 9.—Spot photograph afforded by zinc blende. Incident X-rays perpendicular to a cube-face, and parallel to a tetragonal axis of symmetry.

X-rays by planes situated at different angular positions in the interior of the crystal. In short, we are in face of reflection of X-rays from planes of atoms in the crystal.

Now a study of the spots reveals the further interesting fact that the pattern shows the full symmetry (that of class 32) of the cubic system to which the
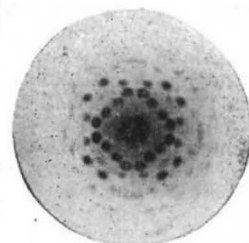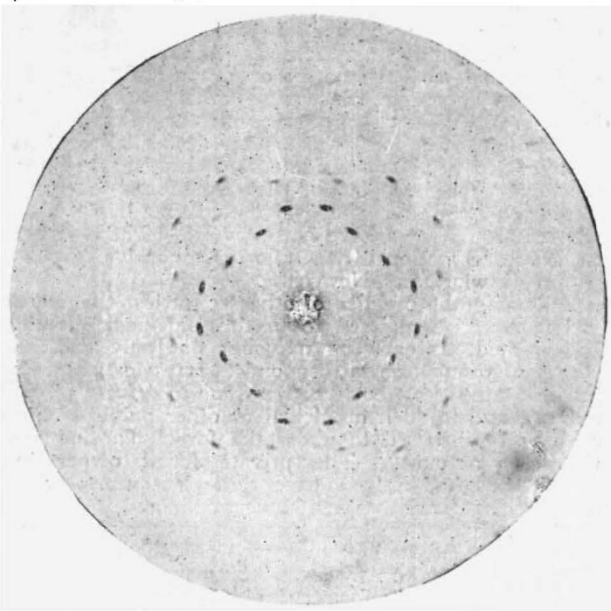

FIG. 10.—Spot photograph afforded by zinc blende. Incident X-rays perpendicular to a cube-face, and parallel to a tetragonal axis of symmetry.

crystal belongs, although zinc blende exhibits the slightly lower symmetry of the hexakis-tetrahedral class (31), one of the formerly so-called hemihedral classes of the cubic system. This clearly proves that it is the planes of similar and similarly situated (same-

ways orientated) atoms in the crystal that are producing the reflections; in other words, the planes of the space-lattice.

At first Laue, who published a separate memoir on the theory of the experiments, considered that it was the space-lattice due to similarly situated zinc atoms which afforded the spot patterns, as he had been engaged with Prof. Summerfeld in experiments relating to the action of zinc on X-rays. But there appears no reason why the sulphur atoms should not be similarly capable of producing reflections of these extremely fine vibrations of corpuscles, and as the space-lattice is the same for both elements, according to all versions of the geometrical theory of crystal structure, there is really no reason why we should not consider the reflections as due to the general space-lattice of zinc blende. Laue considered the "molecules" of the crystal to form a three-dimensional grating—that is, a Raumgitter—and that each molecule is capable of emitting secondary vibrations when struck by incident electromagnetic waves from the X-ray bulb; also that the molecules are arranged according to the simple cube space-lattice (No. 1). The incident waves being propagated parallel to one of the cube axes (edges), the wave-surfaces will be parallel to the plane of the other two cube edges. He then considers the spots to be interference maxima of the waves scattered by the orderly arrangement of the molecules in the crystal. The equations of condition were next found for interference maxima of direction cosines α, β, γ, and for incident wave-length λ, and from the position of each spot the direction cosine of the pencil of rays which formed it was calculated, assuming all the transmitted pencils to come from the centre of the crystal. Thirteen spots in each quadrant were investigated, and in every case Laue's equations were satisfied; hence, the conclusion that the spots are due to interference of secondary Röntgen radiation appears to agree with the positions of the spots, provided only radiations of certain definite wave-lengths are present in the incident rays.

The lecturer pointed out, in an article in NATURE of November 14, 1912, that the structure of zinc blende was probably not so simple as had been assumed by Laue, and that the space-lattice with a point at the centre of each side of the cube (No. 3) was the more probable one, the structure being that assigned to it by Barlow and Pope, as already described in this lecture.

A satisfactory explanation has since been advanced by W. L. Bragg, which does accord with this structure and with other essential conditions referred to by the lecturer, altogether avoids the assumption of only a few wave-lengths, and agrees with a simple reflection of unchanged X-rays from the planes of points of the general space-lattice of zinc blende. He regards the incident radiation as composed of a series of independent pulses, which, falling on a number of atoms definitely scattered in a plane, are separately reflected, each atom acting as a centre of a secondary wave, and the whole building up a wave-front. The interference maximum is thus due to the reflection of the incident pulses from a system of parallel planes of similar atoms, that is, from one of the parallel series of planes of the space-lattice. Now besides the principal planes of the space-lattice, the cube planes, the points of the space-lattice also lie in a considerable number of other planes, all of which are possible crystal faces corresponding to rational indices. For instance, the octahedral planes are very easily traced, as also those of the rhombic dodecahedron. A minute fraction of the energy of a pulse traversing the crystal will be reflected from each parallel plane in succession, and the corresponding interference

maximum will be produced by a train of reflected pulses. The crystal thus actually manufactures rays of definite wave-lengths, just as a diffraction grating does, the only difference being here in the extremely short length of the waves, which is the very reason why X-rays can penetrate in this manner into the Raumgitter structure. Each incident pulse produces a train of pulses, resolvable into a series of wave-lengths, λ, $\lambda/2$, λ_3, $\lambda/4$, &c., where $\lambda = 2d \cos \theta$, d being the shortest distance between successive identical parallel planes in the crystal, and θ the angle of incidence of the primary X-rays on the plane of points of the space-lattice. The intensity of any spot depends on the energy in the spectrum of the incident radiation characteristic of the corresponding wave-length, and this varies considerably so that certain parts of the spectrum are much more pronounced than others. Also it depends on the number of reflecting atoms in the plane—that is, on the reticular density of the possible crystal face corresponding to the plane. Hence, the greater the reticular density, the more intense the spot produced in the photograph. As reticular density is also proportional to importance of face, the primary faces having the greatest reticular density, it follows that the most important facial planes reflect the intensest spots, a fact which may prove of great value in enabling us to discover the real primary planes in doubtful cases. Each spot reflected by a plane (considered as passing through the origin and two other points) lies at the intersection of two ellipses, and the figure on the screen, showing an analysis of one of the spot photographs, exhibits this clearly. Indeed, the plane of atoms corresponding to any spot can be found from the two ellipses; for each ellipse is the section of a cone by the plane of the photographic plate, the axis of the cone being the line joining the origin (centre of the triaxial system, and considered as one of the three points determining the plane) and the particular atom (the second or third point of the three, of definite coordinates), and the generator of the cone being the incident beam.

The interesting results of Bragg are in full accord with the assumption of the centred-face cubic space-lattice (No. 3), but not with either the simple-cube or the centred-cube space-lattice (Nos. 1 and 2). They also account for the elliptical shape of the spots. The amount of ellipticity depends on the distance of the photographic plate from the crystal. When the two are very close the spots are round, but they become more and more elliptical as the plate is receded (compare Figs. 9 and 10). The phenomenon is due to the fact that the initial rays are not strictly parallel, and the effect will be clear from the next slide. The vertically diverging rays striking the reflecting planes of the upper part of the crystal meet them at a less angle of incidence than those of the lower part, and so the reflected rays converge. Horizontally diverging rays, however, diverge still more on reflection. Hence the section of the reflected beam is an ellipse with major axis horizontal.

It is of importance to note that the centred-face cubic space-lattice is characteristic both of the arrangement of identically (sameways) orientated and environed atoms of the same element, zinc or sulphur, and of the atoms of both elements regarded as equal spheres in contact. In the slide already shown (Fig. 5), of Barlow and Pope's model, the spheres of sulphur are coloured yellow to distinguish them from the grey-coloured spheres of zinc. If we ignore the colour and consider them as similar spheres, we see that they form the centred-face cubic arrangement. The hemihedral nature of zinc blende is, however, very likely connected with some real difference of

volume between the atomic spheres.[5] As the spot figure is holohedral it would appear to be due to the space-lattices of similarly placed atoms of either (but in each lattice only one) element, rather than to the spheres of the combined system of atoms.

This latter conclusion is further borne out by the result of the new work by Laue on quartz. The photograph now shown, so kindly sent by Prof. Laue, exhibits the trigonal nature of the symmetry very clearly, and Prof. Laue informs me that the same figure is afforded by both right and left quartz, so that it does not reveal the hemihedral character of quartz, but possesses the full holohedral symmetry of the trigonal space-lattice, and exhibits the threefold nature of the axis of symmetry which is perpendicular to the plate and along which the X-rays were directed.

Prof. Laue has also experimented with the crystals of a number of other cubic substances, and, like zinc blende, they all show holohedral symmetry about a tetragonal axis.

W. L. Bragg has found that stronger photographs of the same nature can be obtained from mica, using nearly grazing incidence, and it is by use of this fact that Mosely and Darwin have been able to study the reflected rays electrically, and found them to resemble ordinary X-rays. By the kindness of Mr. Bragg, a diagram of his apparatus and a positive lantern slide of one of his mica spot photographs are exhibited on the screen.

Incidentally these experiments appear likely to throw light on the much-debated question of the nature of the X-rays. As all the experiments unite in indicating that a fraction of the X-rays suffers reflection at the planes of atoms parallel to the more important possible crystal faces, all being planes of atomic points of the space-lattice, it would appear that the X-rays are some type of wave-motion, or at any rate some kind of pulse with an extended wave-front. Yet after reflection they retain the same corpuscular character which Prof. W. H. Bragg has shown they possess. For the liberation of a high-speed electron from an atom traversed by the X-ray cannot be explained, according to Rutherford, unless it be supposed that the energy of the X-ray is concentrated over a minute volume, and can be given up in an encounter with a single atom. Hence these experiments show that the X-rays possess at the same time the apparently opposite properties of extension over a wave-front and concentration in a corpuscular point.

It appears to the lecturer that the simpler explanation is that we are truly dealing with waves, but that the wave-lengths of the X-rays are excessively short, approaching atomic dimensions, and that the amplitude of the effective waves is actually smaller than the reflecting atom. This view that the X-rays are waves is further supported by the results of some experiments just completed by Barkla, in which a diverging pencil of X-rays was directed on a crystal of rock-salt, and the issuing rays received on a photographic plate in the same manner as in the experiments already described. The developed plate shows a new phenomenon, namely, striation of the spots obtained by reflection from the planes of atoms of the space-lattice, especially in the reflections from the cubic cleavage planes. The striations are, in fact, true interference bands, due to interference of the reflections from equally spaced parallel planes of the space-lattice. By the kind courtesy of Prof. Barkla, two of these interesting

5 Prof. T. W. Richards shows (*loc. cit.*) how four molecules of ZnS, each composed of an atom of zinc and an atom of sulphur of very different volumes, can form the cubic crystal unit of an edifice possessing cubic systematic symmetry, the different volumes of the two kinds of atoms causing it, however, to exhibit hemihedral class-symmetry.

photographs are projected on the screen. On the assumption that the X-rays are waves, and that the reflecting plane is one passing through corresponding portions of single NaCl molecules—which agrees with the choice of a representative point from each simple molecular grosser unit, or of a similarly situated atom of one of the two chemical elements present in each molecule NaCl to act as such representative point of the space-lattice—Barkla has calculated that the wave-length is the one hundred and sixty millionth of a millimetre, 0.6×10^{-8} mm. If the grosser unit be polymolecular, the wave-length works out larger, being proportional to the cube root of the number of atoms in the molecule. If eight molecules form the grosser unit of sodium chloride crystals, as suggested by some chemists, the wave-length is found by Barkla to be twice this value, namely 1.2×10^{-8} mm.; and if sixteen molecules of NaCl are comprised in the grosser unit, as would be the case if Barlow and Pope's structure for the cubic binary compounds be correct (the space-lattice in the case of rock-salt being that of the simple cube, No. 1), the wave-length would be still longer, about the seventy millionth of a millimetre, 1.5×10^{-8} mm. Now it is very interesting that these values are of the same order as those derived from determinations of the velocity of electron ejection, which varied from 1 to 2×10^{-8} mm.

The most trustworthy recent estimations of the size of a molecule of rock-salt indicate a diameter about 3×10^{-7} mm. Hence the diameter of a crystallographic molecule 8NaCl would be 6×10^{-7} mm., and of 16NaCl about 7.5×10^{-7} mm.

It should be emphasised, in concluding the account of this fascinating new field of research, that all these reflections occur in the body of the crystal, and are not surface effects. Cleavage planes usually afford stronger results merely because they are generally primary planes of high reticular density. The effect is sometimes heightened by conducting the X-rays at nearly grazing incidence; but this is by no means necessary, and in Laue's experiments several of the planes were inclined as much as 30° to the incident rays.[6]

The experimental proof of the existence of the space-lattice imparts all the more confidence in approaching the other great advance which has lately been achieved. The completion of the four-volume catalogue of crystallographically measured substances by Prof. von Groth provokes the question: What more is needed in order to enable a crystallised substance described in this book to be recognised by means of a few measurements on the goniometer? For it is now proved up to the hilt that, except in the cases of cubic crystals identical in angles in accordance with their perfect symmetry, every solid crystallisable substance is characterised by its own peculiar crystalline form and interfacial angles. This is quite true, even to the last minute of angular measurement, when the conditions of crystallisation are ideal. When thus perfect, even isomorphous sub-

6 Since this lecture was delivered, the following further experiments with X-rays and crystals have been described in NATURE (1913, vol. xci., pp. 111, 135, and 161). H. B. Keene has obtained with crystals of galena, mica, and rock salt analogous results to those of Laue, Friedrich, and Knipping, the spot diagrams corresponding to the holohedral systematic symmetry in each case. T. Terada has found that the transmitted rays may be rendered optically visible by means of an ordinary fluorescent screen, provided the pencil of rays be from 5 to 10 mm. in diameter and the crystal adequately transparent to the rays; this latter he found to be the case with crystals of alum, borax, cane-sugar, fluorspar, mica, rock crystal, and rock salt, in thicknesses of 4 to 10 mm. M. de Broglie has obtained spot diagrams similar to those of Laue, Friedrich, and Knipping with fluorspar, magnetite (using an octahedron face), and rock salt; but all the spots were striated with parallel fringes. Finally, Owen and Blake have obtained what appears to be a line spectrum of X-rays by using the surface of a crystal of gypsum as a diffraction grating. The lines were always the same with different crystals, using the same X-ray bulb, but the different lines varied in intensity with the hardness (degree of vacuum) of the bulb. The evidence from the action of crystals on X-rays is thus accumulating that the X-rays are waves of exceedingly short wave-length.

stances show differences among themselves to the extent of a definitely measurable number of minutes. But such perfection of growth is not easy to attain, and, in ordinary crystallisation without special precaution against disturbance, is rarely found. The essential crystallographic measurements can, however, be made in an hour's time, provided use be made of the two- or three-circle form of goniometer, such as the excellent one devised by Dr. Herbert Smith. This form of goniometer enables all the needful measurements of the interfacial angles to be made with a single setting of the crystal on the wax of the holder. But practical difficulties have hitherto still stood in the way. Excellent as is von Groth's classification—and the most suitable for a work of reference of the full and comprehensive character of this permanent monument of the master's industry and wide knowledge of chemistry, related compounds being arranged and compared in close proximity—the very nature and size of such a work renders it unsuitable for the purpose of discovering rapidly the chemical composition of a substance from its geometrical elements. An index of substances arranged in the order of their symmetry and the numerical values of the crystal constants within the system is what is needed, and this has now for the first time been drawn up for the ten thousand measured substances by Prof. von Fedorow.

Another difficulty then presents itself. It often entirely depends on how a crystal is held in space, that is, which direction in it is regarded as the vertical axis, which the right-and-left axis, and which the front-and-back axis, as to what the nature of the crystal constants (elements) will be. Moreover, even if two different observers choose these similarly, they may select a different parametral plane (a fourth face other than the three faces parallel to the axes, and cutting off unit lengths from the latter) to determine the axial ratios. Hitherto, beyond a few arbitrary rules —for instance, that the right-and-left axis of a rhombic crystal shall be longer than the front-to-back axis —there has been no definite guiding principle for the determination of the setting. Prof. von Fedorow has now given us one, by means of which we can be sure which are the real vertical faces (prismatic or pinakoidal), which is the basal plane (the pair of top and bottom faces), and which set of pyramid faces are the important ones fixing the relative axial lengths. The true setting has been determined by Prof. von Fedorow for every one of the substances in his index, and the crystal elements for such setting calculated.

The mode of classification adopted in this index-catalogue is based on the values of the five fundamental angles which, in general, characterise the crystals of any specific substance. A cubic crystal has definite angles which are entirely fixed and rendered invariable by reason of the perfect symmetry. At the other extreme come triclinic crystals, the general case, in which all five fundamental angles are different and quite independent of each other. On monoclinic crystals there are three independent angles, from which the other two can be calculated. Rhombic crystals have only two independent angles, which, if measured, enable the other three to be calculated. Hexagonal, tetragonal, and trigonal crystals possess only one angle independent of the symmetry, determinative of the relative length of the unique axis of hexagonal, tetragonal, or trigonal symmetry.

The first object of von Fedorow in order to arrive at the correct setting is to decide which are the primary axial-plane and parametral faces; and he is wonderfully aided here by the discovery of the fact

that the faces most extensively developed under ideal conditions of growth are those over which the points of the space-lattice are most densely strewn. Hence, von Fedorow tries to discover the faces of greatest reticular density, the primary faces, by calculation. For it is a well-known fact that the most diverse habits—due to different faces being most prominently developed under different conditions of environment— are shown by the crystals of the same substance.

Having thus determined the correct setting, and measured the principal angles, including the five fundamental angles, the results are recorded in the index-table in an abbreviated symbolic form if the substance be a new one, or, if it has previously been measured, and therefore appears in his index-table, he discovers the fact at once by the identity of the elements found with those of a substance given in the table. The average time occupied in all this by Prof. von Fedorow or one of his skilled assistants is about two hours. Mr. T. V. Barker, who studied with Prof. von Fedorow before acting as demonstrator of mineralogy at Oxford, has been of considerable help in submitting the new method to a very severe test, from which it has emerged with flying colours. He collected, at Prof. von Fedorow's suggestion, fifty specimens of substances which had been crystallographically examined in this country and described in the recognised publications. Five of these were furnished by the lecturer, six others by Prof. Armstrong, with the aid of Messrs. Colgate and Rodd, others by Drs. Chattaway and Drugman and Mr. Marsh at Oxford, and the remainder by Mr. Barker himself. Each specimen was only marked by a number, no name or formula being given, on its dispatch to St. Petersburg. The result was that Prof. von Fedorow identified without any difficulty forty-eight of the fifty substances. The crystals of one of the two others were too imperfectly developed to be of use, and the fiftieth specimen was that of a substance which it was afterwards discovered had never hitherto been measured, a fact which was first indicated by its elements not tallying with those of any substance mentioned in the table. This latter occurrence confers even greater confidence in accepting the new method.

It thus appears that in Prof. von Fedorow's hands, or those of his pupils, the method is practically infallible, provided the crystals are well developed and not of cubic symmetry. If the latter perfect symmetry be developed, reference must be made to the optical properties, which the lecturer has always insisted have been far too much neglected, and are here seen to be indispensable. The optical methods themselves, moreover, as regards their use with small crystals on the polarising microscope, have been further perfected by von Fedorow, his universal stage placing the rapid methods of two- and three-circle goniometry at the disposal of the microscopist. It must also be remembered that Prof. von Fedorow's method does not discriminate between the members of isomorphous series, as the crystals usually available are not of the high degree of perfection requisite in order clearly to substantiate the last few minutes of any particular angle; for the differences of angle between the members of series formed by metallic family analogues have been shown by the lecturer to be very minute, although unmistakable given the most perfect crystals, and have also been found to obey the law of progression according to the atomic weight of the metal. For instance, ammonium zinc sulphate was simply returned by Prof. von Fedorow as a member of the isomorphous series of monoclinic double sulphates and selenates crystallising with $6H_2O$. Qualitative analysis would be necessary after

all, in order to discover the actual member of the series present. Moreover, there are certain features of Prof. von Fedorow's own peculiar version of the theory of crystal structure, such as his idea about pseudo-cubic and pseudo-hexagonal types, and his dealing in consequence with many substances as being deformations of a higher symmetry than they actually show, which to the lecturer appear unnecessary complications likely to discourage the use of the new method. But these defects can, and doubtless will, be eliminated as the method becomes practically applied. That crystallochemical analysis will ever entirely replace qualitative chemical analysis, however, is neither to be expected nor desired, even if alone on the ground of the admirable training and experience in chemical operations and principles which chemical analysis affords.

In conclusion, it must be obvious that a great advance has really now been made in crystallography. For the geometrical conception of crystals as homogeneous structures, based on the fourteen space-lattices as the grosser structures and the 230 point-systems as the ultimate atomic structures, has been not only theoretically perfected, but proved by direct experiment to represent the actual fact, by the epoch-making work of Laue, Friedrich, and Knipping. The descriptions and chemical relationships of all the ten thousand measured substances have been brought together in the great book of Prof. von Groth, and the material further sifted, reduced to correct setting, and arranged according to symmetry and elements by Prof. von Fedorow, in a tabular form immediately available as a reference index for identification purposes, thus providing the material for a true crystallo-chemical analysis. The science of crystallography is thus now placed on a secure foundation, supported equally by mathematics, geometry, and experiment, and its natural data are rendered available for chemists and physicists alike.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—Mr. C. W. Dyson Perrins, a former member of Queen's College, has offered to give the sum of 5000*l.* towards the erection of the proposed new chemical laboratory, if such sum is required after the expenditure of the 15,000*l.* granted for the purpose by the trustees of the Oxford University Endowment Fund.

THE honorary degree of LL.D. was conferred on Mr. W. Botting Hemsley, F.R.S., on July 8 by the University of Aberdeen.

DR. W. C. McCULLAGH LEWIS has been apppointed to the chair of physical chemistry in the University of Liverpool, in succession to Prof. F. G. Donnan, F.R.S.

THE following honorary degrees were conferred by Queen's University, Belfast, on July 9 :—*D.Sc.*: Prof. Norman Collie, F.R.S.; Sir Joseph Larmor, M.P., F.R.S.; Sir Arthur Rücker, F.R.S. *LL.D.*: Sir Donald MacAlister.

AMONG the bequests of the late Lord Avebury is one of 1000*l.* to the University of London to found a prize in mathematics or astronomy in memory of his father, Sir John William Lubbock, first Vice-Chancellor of the University.

DR. J. RITCHIE, superintendent of the laboratory of the Royal College of Physicians, Edinburgh, has been appointed to the new chair of bacteriology instituted in the University of Edinburgh, under the bequest of Mr. Robert Irvine, Royston, Granton.

AMONG recent appointments at University College, London, are :—Dr. Marie Stopes, lecturer in palæobotany for three years; Miss Winifred Smith, lecturer in taxonomy for three years; Dr. Paul Haas, demonstrator in organic and applied chemistry and in chemical physiology, and Mr. H. Terrey, demonstrator in chemistry to medical students; Mr. N. F. Kelsey, demonstrator in mechanical engineering, and Mr. D. W. Fletcher in graphics.

THE following official announcement referring to the Education Bill has been issued on behalf of the Government :—"The measure which will shortly be introduced by Mr. Pease in the House of Commons, although it is technically described as an Education Bill, is in reality only a one-clause measure designed to enable the Government to afford a limited amount of immediate relief to education authorities. It will, when introduced next week, form a not inappropriate peg upon which to hang a statement of the Government's policy in the development of a national system of education."

AT the annual graduation ceremony at St. Andrews University on July 10 honorary degrees of LL.D. were conferred on Lieut.-Col. Sir C. H. Bedford and Dr. G. A. Boulenger, F.R.S., among others. In addressing the graduates the principal, Sir James Donaldson, said that both France and Germany have come gradually to form an exact notion in regard to university work. Their idea is that after the culture obtained in the secondary schools the students who are to proceed to degrees should spend three years at the university and should devote themselves to the original study of certain subjects in which they find their interest. There must be entire freedom for the student to form his own plans and studies and entire freedom for the professor to search for the truth for its own sake in disregard to consequences. The Germans have kept to that idea since 1815, and the French have now come to the same conclusions. We are in many respects far behind this ideal, and we cannot expect to be a match for those nations in the great conflicts of the world, but it is the duty of young and old to look into the question, particularly at this time, and see if we cannot do something to put ourselves on an equality with Germany and France.

THE recommendations made in the second report of the Advisory Committee on the distribution of Exchequer grants to universities and university colleges, which was issued last February, having been approved by the Board of Education, the Committee proceeded with a further consideration, in conjunction with the universities and colleges, of the federated superannuation scheme adumbrated in the second report. In its third report the committee outlines a federated scheme of superannuation for professors and other members of the staffs of colleges. Two problems were debated; first, the selection of a limited number of insurance companies to undertake the contracts involved by the superannuation system; and secondly, the drafting of a suitable form of legal agreement between the institution and the members of the staff which when adopted by colleges concerned would give practical effect to the principles set out in the second report. The form of agreement indicates, by means of alternative readings, the various forms which will be necessary to meet different cases. In practice institutions will probably find it convenient to have separate forms of agreement to meet different types of cases. The superannuation scheme itself expresses in legal terminology the principles outlined in the second report, and in order to