

The first experiments, performed in 1922 by G. E. Dean and R. D. Stuart showed that whereas clear melts were readily obtained, the solidified mass was opaque. The problem was attacked anew last year by C. S. Draper, who succeeded in proving that the opacity was due in part to numerous small crystals. These crystals could be made to grow by slow cooling through the freezing point and below, until they were of the order of magnitude of one sixteenth of an inch across. No tests with ultraviolet radiation have been made, but in visible light they appeared to be perfectly transparent. They adhered strongly and the entire mass possessed the cleavage planes characteristic of natural fluorite.

The work is being carried on by M. W. Fort, a graduate student, and the successful growth of large, clear crystals is predicted.

REVIEWS

DIE METALLOGENETISCHEN EPOCHEN UND GEBIETEN

VON SIBIRIEN. W. A. OBRUTSCHEW, Abhandlungen zur Praktischen Geologie und Bergwirtschaftslehre, vol. 6. *Berlin*, 1926. Published by Wilhelm Knapp, Halle (Saale). 63 pages. Price R. M. 5.50

It is a rather difficult task to present an adequate review of this interesting article as the author lists one hundred and thirty-six references from which he has drawn his material and then attempted to condense it into fifty-five pages.

After a short introduction an historical sketch is given covering the main points on the geology of Siberia. A rather detailed discussion follows dealing with the metallogenetic periods and metallogenetic epochs of Siberia. This portion comprises the major part of the article. The classification used is that based on the author's own classification of ore deposits, which was reviewed in *Am. Mineral.*, Vol. 11, p. 190, 1926. The discussion closes with a short review of the older literature and a general summary of results.

This contribution should prove interesting to readers who wish to acquaint themselves with the mineral wealth of Siberia, but the vast accumulation of data and confusing geographic names make the reading somewhat difficult. A map of Siberia indicating the principal ore deposits accompanies the article. This map together with the comprehensive list of references contribute much to the value of the paper.

TJ. L. REITSEMA.

ENTWICKLUNGSGESCHICHTE DER MINERALOGISCHEN

WISSENSCHAFTEN. P. Groth. VI+266 pages. Julius Springer. *Berlin*, 1926.

It is indeed fitting that the eminent teacher and investigator, Professor P. Groth, for many years Director of the Mineralogical Laboratory of the University of Munich and also the founder and first editor of the *Zeitschrift fuer Krystallographie und Mineralogie*, should bring together the salient facts concerning the development of the mineralogical sciences from the very beginning down to the end of the nineteenth century.

The evolution of our knowledge of the geometrical, physical, and chemical properties of crystals is discussed in Part I. This survey is very timely, especially in view of the recent important developments in these fields which were made

possible through the application of x-rays, and which were not dreamed of twenty-five years ago. Some of the subjects treated in this portion of the book are: observation of the constancy of interfacial angles and the description of crystal forms; investigation of the physical properties and the structure of crystals; introduction of crystal axes and the gradual development of the fundamental laws of geometrical crystallography; recognition of the relationships between the geometrical development of form and the optical properties of crystals; and the symmetry of crystals and the theory of crystal structure.

Part II is devoted to what may be termed the recognition of minerals. Here the description, classification, and nomenclature of minerals, as well as the history of important mineral collections and laboratories are considered. There are also chapters on the paragenesis of minerals, ore deposits, composition of minerals, decomposition of minerals, and formation of minerals in nature and by artificial means in the laboratory.

The concluding chapter contains very useful short biographical sketches of thirty-seven outstanding contributors to the mineralogical sciences among whom we are pleased to note three Americans, Genth, Brush, and Penfield.

The volume is a splendid testimonial to the energy and perseverance of one of our eminent mineralogists who, although eighty-three years of age and with greatly impaired eyesight, has been able to complete this splendid contribution to our science.

EDWARD H. KRAUS.

THE LAWS OF CHEMICAL CRYSTALLOGRAPHY¹

An unusually interesting article on the significance of atomic dimensions in crystal structure, isomorphism, etc., has recently been published by Professor V. M. Goldschmidt of the Mineralogical Institute of the University of Oslo (formerly Kristiania), Norway, and a review of the important points brought out may be of interest to readers of the American Mineralogist to whom the original paper is not accessible. His thirteen principal theorems (*Sätze*) are here translated in full.

1. The crystal structure of a substance is conditioned by the size and deformability (*Polarisierbarkeit*) of its components; the latter term comprises atoms or their ions and atomic groups.

A. LAWS CONCERNING SIZE OF CRYSTAL COMPONENTS (*Krystallbausteine*)

Crystals are regarded as made up of spherical or ellipsoidal domains, in contact with one another, which are characterized by their radii, or the distances from their centers to the contact-points.

2. The radius of a crystal-component is conditioned by the atomic number and the state of the atom concerned.

The changes of radius with atomic number and with state of ionization are shown in the following tabulation:

Li ⁺ 0.78	Na ⁺ 0.98	K ⁺ 1.33	Rb ⁺ 1.49	Cs ⁺ 1.65	Pb ⁺⁺⁺⁺ 0.84	Pb ⁺⁺⁺ 1.32	Pb [°] 1.74
	Mg ⁺⁺ 0.78	Ca ⁺⁺ 1.06	Sr ⁺⁺ 1.27	Ba ⁺⁺ 1.43	Te ⁺⁺⁺⁺ 0.89	Te [°] 1.43	Te ⁻⁻ 2.03
	F ⁻ 1.33	Cl ⁻ 1.81	Br ⁻ 1.96	I ⁻ 2.20			
	O ⁻⁻⁻ 1.32	S ⁻⁻⁻ 1.74	Se ⁻⁻⁻ 1.91	Te ⁻⁻⁻ 2.03			

¹Review of Professor V. M. Goldschmidt's work, *Die Gesetze der Krystallochemie*, *Naturwissenschaften*, 21, 477-485, May 21, 1926.

3. The radius lengthens with increasing negative charge, and shortens with increasing positive charge. The lengthening of the radius of the atom itself (not the domain) with increasing negative charge is to a certain extent compensated by increasing Coulomb attraction between the components, while on the other hand the shortening of the radius of the atom itself with increased positive charge is intensified by the increased Coulomb attraction.

4. In crystal-components of like order and like state the radius is approximately constant. When however the states are dissimilar the radii may be markedly different.

The principal change in the state of an atom concerns its degree of ionization.

5. There are a finite number of mutually incommensurable groups of space-lattice-types, each group characterized by a like state of one or more of the crystal-components.

It is noteworthy that crystals of the sphalerite, wurtzite, and cuprite space-lattice-types are commensurable with those of most of the free elements, and apparently contain atoms in non-ionized condition. In addition to being conditioned by order and state, the radii are more or less influenced by the arrangement and nature of surrounding atoms, as well as by the thermodynamic factors concerned in thermal expansion and compressibility.

B. LAWS CONCERNING DEFORMABILITY OF CRYSTAL-COMPONENTS.

1. Deformability

The deformability of a single crystal-component is primarily dependent on its radius and its charge. The deformability increases with increasing radius, and on the other hand decreases with increasing positive charge. The influence on degree of deformation due to neighboring-components depends on their arrangement and their character. The more symmetrically they are arranged, the less their deforming effect. Moreover, some of them are weakly, others strongly, deforming, their influence being heightened by increased charge, lessened by increased radius.

6. When a deformable crystal-component comes into contact with a deforming crystal-component, the distance between their centers (the sum of their radii) becomes less than the sum of the radii they normally exhibit.

The diminution in interatomic distance may be very marked as in radicles such as nitrate-ion, carbonate-ion, sulfate-ion, etc.

B. 2. Counter-deformability. (*Kontrapolarisation*).

7. Composite crystal-components can become more or less extended in space by the influence of neighboring strongly deforming components, and this phenomenon is termed counter-deformability; in the limiting case, this effect leads to the complete disruption of the radicle, and in extreme cases it may result in developing a new radicle, made up of the deforming component together with the portion of the original radicle which splits off.

The extreme case is illustrated by the spinel group, in which the strong deforming effect of the Mg leads to the splitting up of the aluminate radicle (Al_2O_4) with the formation of the new radicle MgO_4 .

C. LAWS CONCERNING ISOMORPHISM.

1. Ordinary Isomorphism

8. Isomorphism between two substances occurs when the relative sizes of the crystal-components and their relative degrees of deformability are equal, within certain limits, or correspond, provided that the empirical chemical formulas of the two substances and also the signs of their electric charges are analogous.

The structures of the members of a number of isomorphous series have been studied by means of X-rays by Goldschmidt and his associates, and it has been found possible to express the limits of dimensions and deformabilities of crystal-components in simple formulas. For instance, the perovskite structure proves to be possessed by the following compounds of formula-type ABX_3 : $CaTiO_3$, $SrTiO_3$, $BaTiO_3$, KIO_3 , $NaCbO_3$, $CaZrO_3$, $CaSnO_3$, $FeMnO_3$, $KMgF_3$, $LaAlO_3$, $LaGaO_3$. The ionic radii of the components of all these substances stand in relation to each other in accordance with the formula $R_A + R_X = \alpha \cdot \sqrt{2} \cdot (R_B + R_X)$, the coefficient α lying between 0.8 and 1.0. When for any combination of atoms α sinks below 0.8, the atoms take up instead the corundum type of space-lattice, as a result of the increased counter-deforming influence of component A. When on the other hand α rises above 1.0, the calcite type of space-lattice is taken up, and with still greater increase the aragonite type. As the result of numerous observations and calculations it may be stated that:

9. Isomorphous miscibility, to appreciable extent and at temperatures well removed from the melting-point curve, occurs when the radii of the crystal-components concerned differ from one another by not more than about 15%.

10. Even ions of quite dissimilar electronic structure (such as Cd^{++} and Ca^{++}) can replace one another in the simplest types of space-lattices.

C. 2. Antisomorphism.

This term is suggested to describe the case where the points of a given space lattice are occupied by atoms of opposite charges; for instance, CaF_2 and Li_2O have the same arrangement, the two cases being termed the fluorite and the antifluorite space-lattice-type, respectively.

10. In antisomorphous crystals mutual isomorphous miscibility appears to be excluded.

C. 3. POLYMERIC ISOMORPHISM

This term refers to cases where a substance with a certain formula is isomorphous with another which has a multiple of that formula, as in the case of rutile, TiO_2 and the "trirutiles" $FeCb_2O_6$ and $FeTa_2O_6$, as well as the "polyrutiles" $ZrSiO_4$ and YPO_4 .

11. In polymeric-isomorphous crystals mix-crystal formation is possible.

D. LAWS CONCERNING POLYMORPHISM AND MORPHOTROPISM.

A simple way of regarding polymorphism is to consider that as the temperature and pressure under which a compound exists change, the radii and deformabilities of its components vary; for a time the substance remains isomorphous with itself, but ultimately a point is reached at which one or the other of these factors exceeds the limits of stability for that particular structure, and a new arrangement is taken up. Accordingly,

12. The chemico-crystallographic phenomena of isomorphism, morphotropism, and polymorphism are most intimately connected with one another. Polymorphism is the morphotropic structure-change, chemical relations remaining constant, conditioned by the influence of thermodynamic factors on the properties and reciprocal effects of the crystal-components; polymorphism occurs, as soon as the limiting-values for self-isomorphism are overstepped.

13. At higher temperatures that type of crystal-structure is stable which can be obtained through substitution of the counter-deforming cation by its next lower homolog.

A few details as to the observational data on which these various theorems are based are given in the article under review, but the bulk of the evidence is contained in a series of papers on the "Geochemical distribution laws of the elements" by Goldschmidt and his collaborators in course of publication in the *Skrifter norske Videnskap-Akademi*, Oslo, 1923-1926.

"I believe," writes Professor Goldschmidt in conclusion of the essay under review, "to have in this communication shown the way in which chemical-crystallography becomes, instead of a mere descriptive, an exact science." He has certainly done crystallographers a great service in having carried out such an extensive series of x-ray measurements on members of isomorphous series as to make possible the recognition of the principles governing isomorphous replacement. He has given the final death-blow to the older view that valence has a direct connection with isomorphism, as a glance at the series of compounds enumerated under the discussion of theorem 8 will clearly show. With the majority of the ideas put forward the reviewer is in complete accord.² The atomic and ionic radii used by Goldschmidt are however, hardly as well established as is implied by the assurance with which they are used, and the reviewer ventures to express the opinion that the values given for the ions of the halogens and oxygen (discussion of theorem 2) will ultimately be found to be about as much too high as those in present use by many workers (the Bragg values of 1920) are too low. If such is the case some of the conclusions as to commensurability of different space-lattice-types (theorem 5), marked deformability of certain crystal-components, (theorem 6), etc., may have to be revised. On the whole, however, Professor Goldschmidt's series of papers, summarized in this essay, represents the most important contribution to chemical crystallography which has appeared since X-rays have been applied to the elucidation of crystal structure.

E. T. WHERRY

PROCEEDINGS OF SOCIETIES

NEWARK MINERALOGICAL SOCIETY

The eighty-fourth regular meeting of the Newark Mineralogical Society was called to order by President T. I. Miller, eighteen members being present. The minutes of the last meeting were read and approved. The secretary reported a total membership of seventy-four with several applications for membership pending. The treasurer reported a satisfactory balance on hand. The special Museum Committee reported that an exhibit would be held at the Newark Museum on December

²He had already arrived at some of them independently, as indicated in articles published in this journal.