

X.—*Memoir on Crystallogenesis.*

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 ABSTRACT.

VARIABLE DEGREES OF CRYSTALLIZING FORCE.—A tendency to assume crystalline forms is a property of all crystalloids; its full or imperfect development depends on external circumstances.

Crystals produced in laboratories are generally inferior to natural crystals of the same substances, probably because of their too rapid formation. The faculty of crystallization is modified by specific dispositions inherent to the substances. There are many distinct types of crystallization, connected with each other by intermediate types, and even with a transition from amorphous to crystallizable substances.

The degree of distinctness of crystals constitutes a fundamental difference. The crystals of many substances are distinct, while below a certain limit of size; but when this is exceeded, the surfaces are interrupted by re-entering angles, or by irregular drusy cavities or excrescences constantly re-appearing when cleft away, so as, at last, to completely destroy their individuality and regularity.

A higher power of crystallization must be ascribed to substances whose crystals preserve their surfaces uninterrupted, even when of considerable size. Such crystals may, indeed, exhibit local irregularities, due to the too rapid increase such as may be provoked by sudden changes of temperature. These defects, however, are subsequently repaired, while in less crystallizable substances they become more and more striking.

The artificially mutilated crystals of certain substances, when plunged into saturated solutions, are very soon converted into perfect crystals. Some substances crystallize easily in isolated individuals, others in irregular aggregations or in binary groups. Certain crystals, especially after having arrived at a large size, are constantly

affected with partial irregularities (rough, uneven, or ribbed surfaces, rounded edges, &c.) appearing always on similar points, the rest of the crystal remaining quite regular.

Crystals of many substances, surpassing in symmetry any natural ones, may be obtained by keeping them suspended in a solution, occasionally changing their position. Independently of the degree of solubility, the crystals of some substances increase very rapidly; others very slowly; some appear in pellucid, others in opaque crystals.

Some substances, although frequently occurring in amorphous or indistinctly crystallized forms, are occasionally under circumstances not yet sufficiently cleared up, obtained in well-shaped crystals. Many substances, especially organic ones, possess a very imperfect power of crystallization, appearing only in the form of dendritic crystalline aggregations, scales, tubercles, or fibres. Such are pyroracemate of magnesia, glycolate of baryta, oxalate of lead, malate of yttria, itaconates of soda, methylo-sulphite of potash, asparagat of zinc, tartrates of baryta, antimony, &c.

Substances occurring as crystalline powders rank not absolutely under this category. Many of them, when magnified, prove to be aggregations of isolated and regular crystals, capable of undergoing normal increase in time and under favourable circumstances. Within four years crystals of ammonia-platino-chloride of the size of a pea, and acetate of soda-uranium of the size of a nut, have been obtained, both of quite regular form.

The limit of increase between regular and abnormal modes of formation is not the same for all crystallizable substances; nor even for the same substance under varying circumstances. Sulphate of potash, acetate of potash-uranium, chloride of barium, chlorate and dithionate of potash, &c., may serve as types of the loss of regularity accompanying the increase of volume. The crystals of dithionate, quite regular as long as they remain small, become irregular and even altogether indistinct as soon as they have reached a moderate size.

Substances possessed of such a power of crystallization that their fragments easily complete themselves to perfect crystals, are not numerous. Such are: iron and chromium-alums, sulphate of cadmium, borate of soda, citric acid, malate of ammonia, citrate of soda, citrate of ammonia with excess of acid, acetate of soda-uranium, dithionates of lime and strontia. The time in which this com-

pletion is perfected essentially depends on the degree of solubility of the substances; which easily take the form of isolated individuals, frequently achieve a notable volume, and are scarcely affected with irregularities even under the most unfavourable circumstances.

Some substances so constantly crystallize into binary groups, that this tendency must be considered as essentially inherent to them. Such are: ferric and cobaltic cyanides of potassium, succinate of soda, valerianite of copper, &c.; and these are connected by intermediate terms with other crystallizable substances.

In crystals inclined to partial defects of formation, these defects are often strictly localized, the rest of the crystal exhibiting such characters as specular surfaces, sharp edges, &c., in perfection. In some substances these defects appear from the very first, in others only in crystals arrived at larger dimensions. Although the increase of such crystals progresses uniformly at every point, the characteristic defects never disappear, and must therefore be considered as essentially inherent to the substance.

The cyanide of potassium and nickel crystallizes in the shape of monoclinous tabular crystals, whose terminal surfaces are constantly opaque and ribbed, those of the prism remaining quite smooth and bright. Oxalate of iron-potash always exhibits a pair of striated surfaces. Arseniate of potash and phosphate of ammonia constantly show curved and opaque prismatic surfaces whenever their crystals have reached a considerable volume.

Formiate of cadmium-baryta, however minute its crystals may be, always has notably striated prismatic surfaces.

The result of over-hasty crystallization, as it takes place in industrial operations, proves that the origin of opaque crystals is not exclusively due to the irregular disposition of their mineral particles. Frequently crystals so produced are as regularly formed as those issuing from slow increase under sedulous care. Most of these substances, limpid in their origin, grow opaque only when having arrived at a considerable volume.

A study of chemical literature shews that a great many crystallogenic experiments have been conducted under most unfavourable circumstances. Thus, the physical properties of many crystallized substances are merely derived from crystals obtained by cooling from hot saturated solutions.

PRESENCE OF FOREIGN SUBSTANCES.—The presence of a heterogeneous substance in a solution acts in a constant and regular way on the crystallization of the dissolved substance. Whenever the admixture is identical with one of the components of the dissolved substance, it merely alters the proportion of its equivalent. In no case are these admixtures embodied into the products of crystallization and their mode of action is as yet wrapped in the deepest obscurity. It has been ascertained that chloride of sodium, which generally crystallizes in cubes, assumes the form of octahedra by the presence of a little urea in its solution, and binoxalate of ammonia crystallizes in peculiarly disfigured forms out of a solution containing a minute proportion of antimony.

There are still other striking instances of this action. Acetate of strontia, easily to be obtained in very large crystals, crystallizes out of a neutral solution with conspicuous terminal surfaces of truncation, of which not the least trace appears when acid prevails in the solution. Chlorate of soda crystallizes out of its unmixed solution into cubes with some hemihedral surfaces. The admixture of sulphate of soda calls forth most perfect tetrahedra with conspicuously three-faced solid angles, and more or less developed hexahedral surfaces. Sometimes such crystals come to considerable size, still remaining perfectly regular. Together with them, other crystals are disfigured, so as to offer the aspect of prisms.

Sulphate of nickel with six atoms of water crystallizes in quadratic pyramids under a temperature between 30° and 40° C. When the solution contains a small proportion of nitric acid, the angles of the pyramids are conspicuously truncated. This may occasionally be observed in crystals formed in an unmixed solution, but then only in a slight degree as long as the crystals remain small. This hydrate crystallizes under a temperature little above 20° C. out of a solution containing a great proportion of free sulphuric acid, provided the evaporation is going on within a closed space and above a substance absorbing water; chloride of barium appears in conspicuously large and regular crystals, when its solution contains traces of chlorides of zinc, cadmium, or mercury.

Nitrate of lead, when crystallizing out of a neutral solution and having grown to some size, is milk-white and opaque. A hot and moderately heated solution, containing free nitric acid, gives, when cooled, transparent and bright crystals with many surfaces.

Sulphate of potash-manganese is only obtained in fine crystals out of solutions in which sulphate of manganese exists in rather notable excess. Such an excess, in smaller proportion, is an absolute condition of its existence. A solution conformous to the proportion of chemical equivalents, when abandoned to spontaneous evaporation, deposits only pure sulphate of potash during a certain time, the excess of sulphate of manganese remaining in the solution.* Acetate of copper-lime crystallizes only from a solution with a notable quantity of acetate of lime. When re-crystallized from its solution in water, acetate of copper is obtained before the double salt. This change is indicated by a change of colour. Hot water, sufficient for a complete solution, takes a green tint in contact with the double salt, having dissolved only acetate of copper. This, having partly crystallized out of the cooled solution, the rest of the solution assumes the beautiful intensely blue tint characterising the bi-basic salt. The same effect is obtained by adding some acetate of lime to the solution. The crystals of the bi-basic sulphates of peroxides of iron and potash or ammonia, separating from a solution with some excess of free sulphuric acid, are conspicuously disfigured and irregular. All these phenomena and many others of the same nature, although ascertained by way of experiment, still remain unexplained as to their causes. Probably they are more frequent than is generally thought, and such causes may have been active in the formation of minerals, impressing on them the crystalline forms which are so often characteristic of certain localities. Certain substances might not be under exactly the same crystallographical and chemical conditions more than once, even after repeated trials; nor could the cause of success or non-success be sufficiently ascertained.

Whoever works simultaneously with many solutions, whose degree of purity is not sufficiently known, and of which some may be forgotten for a time, is likely to meet with quite unexpected results. Casually formed crystals may, at times, far exceed in perfection those on which the greatest care has been bestowed. Sometimes the chemical nature of crystals is different from the composition of those which are ordinarily deposited by the solution. This is

* These crystals offer a notable instance of the action of mechanical mutilation. If one extremity of these lengthened tabular crystals is broken away, the regularities of the surfaces at the opposed extremity disappear in the course of increase; cavities take their place, and the continuity of the structure is disturbed.

especially the case with hydrates. Heterogenous substances present in the solution may be productive of new crystallized combinations, whose nature, indeed, may be ascertained by chemical analysis, but which cannot be re-produced, although their constituents are brought together in the same proportions and apparently under the same circumstances. Failures in the reproduction of crystallizable chemical combinations would not therefore be a sufficient reason for denying their real or possible existence.

EFFECTS OF TIME.—A limit of increase in crystals is properly speaking not observable. Many substances, however, even while their crystals have not increased beyond a relatively small size, lose their regularity by unconformous aggregation of their molecules, and grow up into shapeless conglomerations without a trace of crystallographical individuality.

The apparently most perfect crystalline surfaces, when examined under a magnifying glass, offer a great many irregularities, such as striations, furrows, &c. When strictly measured, the angles of the individuals of one and the same substance offer slight differences. The juxta and super-position of the molecules, by whose aggregation crystals are constructed, are not subject to the rigour of geometrical rules, and any crystal may bear in itself a tendency to irregularities becoming more and more conspicuous as it increases in size. During the increase molecules may be again aggregated in a regular way, thus parallelizing the irregularities; this process, however, seems not to continue over the whole surface, and, in general, large crystals are not so regular as smaller ones of the same species. No such disfigurations, as they appear on artificial crystals submitted to a long-lasting increase in our laboratories, are conspicuous on crystals of minerals, whatever may be their occasionally colossal size. Probably their formation has progressed in a less hurried way, in consequence of the very low degree of solubility of their component substances in their respective menstua. The most perfect artificial crystals are obtained from difficultly soluble substances. Whenever such a substance possesses a high faculty of crystallization, so that its first crystals are not affected with disfiguring irregularities, an increase continued through years may produce crystals as large and as perfect as any natural ones.

The increase of volume, without regard to irregularity is unlimited; increase with preservation of the original regular forms is limited, at

least in many substances. Experiments, continued through years with more or less soluble substances, have not led to finding out a term of their increase as individuals. A number of substances possessing the faculty of forming large crystals achieve a notable size within a few days. Others remain very small, even minute, during the same time, but may achieve the same size as the first ones, by successive and long-continued increase. The time of increase is a specific quality of the substances independent of their degree of solubility. The racemates of potash and soda are nearly equally soluble; however, the last one appears in* small crystals, achieving scarcely in years the size to which the first one arrives in as many months, although with an indefinite space of time it may be formed into large regular crystals. Borate of soda is difficultly soluble in comparison with racemate of soda, yet it appears at first in far larger crystals, and its increase, during the spontaneous evaporation of both solutions, proceeds with far more celerity.

The absolute size of a crystal is no criterion of the time of its increase. The substances generally quoted as forming "large crystals" are, for the most part, those first appearing in considerable size. Those characterized as forming "small crystals" are such appearing first in minute size, not including their further increase. As to the first class, a few primary nuclei attract the whole of the fixed substance contained in the solution; as to those of the second class, many such nuclei exist in the beginning, each increasing at the expense of the dissolved substance.†

Whenever the quantity of this substance exceeds the power of increase of the already formed crystals, new primary nuclei are formed. These phenomena are conspicuous, both in hot saturated solutions gradually cooled, and in solutions left to spontaneous evaporation. Crystals of quite astonishing size may be obtained in short times whenever the quantity of substance in solution accords with the power of assimilation of the primary nuclei, and the substance itself is endowed with an energetic faculty of increase. Sulphates of iron and copper, acetate of lead, tartaric acid, &c., in enormous crystals, are obtained by industrial operations. Such crystals have been left to increase during a long time without any

* The first appearing crystals are those which become visible at the cooling of a hot saturated solution, or at the first beginning of spontaneous evaporation.

† Nearly all solutions when left in complete repose for some time, become supersaturated.

alteration of their normal structure. Chlorate of potash, resulting from identical industrial operations, constantly appears in thin lamellæ, never coming to a notable size by slow increase without undergoing complete disfiguration. In a solution saturated when hot and left to cool, the amount of dissolved substance, accessible to the primary nuclei, must be proportional to the volume of the solution, and to the difference of solubility in heat and after cooling. Whenever a solution is brought to crystallization by spontaneous evaporation, the volume of the solution acts on the quantity of crystallizing substance, together with the degree of super-saturation, which it comes to when left to repose.

Super-saturation is, in many cases, an abundant source of increase to the first-formed crystals. The difference between a normally saturated and a super-saturated solution is sometimes not more notable than the difference of a solution saturated when hot and subsequently cooled. Rapidly increasing crystals of substances whose solutions are capable of bearing a high degree of super-saturation, acquire in a few days remarkable dimensions in a cool solution left in absolute repose. Such are arseniate of soda, oxalate of ammonia-chromium, &c.

Another group of substances, apt to appear in large crystals, show this faculty only when due time is left to them. Such are, chlorate of baryta, hypo-sulphate of soda, platino-cyanide of magnesium and many others. The circumstances prevailing at the first do not re-appear, thus the increase is never again as rapid as it was in the initial period of formation.

MECHANICALLY INDUCED VARIATIONS.—Conclusions from the size of any crystals, as to the time occupied in attaining their present volume, are only admissible whenever the specific faculty of crystallization of the substances in question is known; and this may probably be the case for natural as for artificial crystals. The formation of some substances may be likewise modified by mechanical operations, as filing, polishing, or cleaving, and subsequently leaving them to further increase, till they are again completely wrapped up into really crystalline surfaces, which occasionally adapt themselves, wholly or partially, to the form of the mechanically modified crystal. Experiments prove the possibility of modifying the crystals treated in this way, by increasing their symmetry or their irregularities, by imparting extension and

permanence to inconspicuous or easily disappearing surfaces, or by calling into existence new secondary surfaces. Substances completing themselves in this way or out of amorphous fragments, into individual crystals, are endowed with an eminent power of crystallization. Professor Frankenheim has tried to explain the increased assimilation of substance along the mechanically altered portion of crystals, by supposing an increase of superficial attraction, the rough fracture of a crystal offering a greater surface than any smooth surface. In fact, however, the increase of superficial attraction is not proportional to the excess of substance adhering to the altered points over the amount adhering to the portions left unaltered. The faculty of spontaneous completion is most conspicuous in sulphate of cadmium, citrate and racemate of soda, bi-malate of ammonia, phosphate of ammonia, dithionates of lime and strontia, &c., as also in some bi-basic combinations as acetate of soda-uranium, ferro-cyanide of potassium, &c. Acetate of uranium-soda, especially in large crystals, offers but slight traces of the three planes at the angles of the tetrahedron, and frequently these surfaces are wholly wanting. They may be obtained to any extent by breaking the tetrahedral angles and by filing away the three edges thus obtained. The ferro-cyanide of sodium crystallizes in tetragonal, less frequently in hexagonal prisms, with four opaque and uneven and two specular surfaces, these last disappearing in the course of increase, but obtainable to any extent by repeated filing in the progress of increase.

Phosphate of ammonia crystallizes normally in lengthened prisms, pointed at both extremities. It may be obtained in short and thick prisms, with conspicuously developed terminal points, by repeatedly breaking away both points.

The twelve secondary surfaces of the dithionates of lime and strontia are more fully developed by repeated breaking away of their edges. Borate and citrate of soda, like bi-malate of ammonia, may be modified at pleasure by a repeated cleaving of their crystals. The symmetrical evolution of crystals by increase of imperfectly developed surfaces, may be promoted by keeping the increasing crystals lying on these surfaces. This proceeding is, of course, only applicable to a limited number of surfaces, and in general only on crystals of the regular and quadratic systems.

VARIATIONS OF TEMPERATURE.—There is a greater number of substances on whose crystals secondary surfaces may be produced,

by exposing them to partial solution and afterwards leaving them to further increase within a spontaneously evaporating solution. A crystal, placed repeatedly in an incompletely saturated solution of its own substance, has its angles and edges rounded, its surfaces being but slightly altered. When brought again into a saturated solution, many crystals acquire new surfaces on the rounded places, which surfaces generally disappear whenever the volume increases notably.

The multiplication of surfaces on crystals, subsequently to their partial dissolution, appears most completely and conspicuously when this alternation of dissolution and regeneration proceeds spontaneously, as is the case under varying temperature. As soon as the temperature of the air in contact with the solution is rising, the crystals, already formed in the solution, are partly dissolved. In the progress of spontaneous evaporation the solution becomes moderately super-saturated, and is most fit for the production of crystals, provided it be kept in absolute repose and secured against subitaneous diminutions of temperature. The disturbances caused by variations of temperature are more or less apparent, according to the degree of solubility of the substances contained in the solution.

A number of substances are characterized by an excessive sensibility to the least agents disturbing crystallization. Their initial crystals, however correct they may be, when slightly disturbed in the progress of increase, lose their regularity and become scaliform. They are easily influenced by variation of temperature, and thus can never be obtained in voluminous crystals. Most of such substances are easily soluble, although a high degree of solubility could not be considered to be the only cause of their characteristic peculiarities. Nitrate of potash appears, at first, in well-formed crystals out of a super-saturated solution. When they are repeatedly turned in order to obtain their increase, they change their shape nearly day by day, and become more and more deformed by alternations of partial increase.* The same is the case with nitrate of soda and with the anhydrous hexagonal chloride of ammonia and cadmium. The tendency to alternating partial abnormal increase, and consequently to deformation, is most conspicuous on the sodium-platinum-chloride Dithionate of potash and nitrate of lead (this last rather difficultly soluble) offer a constant change in the formation of their edges and

* Large and regular crystals of nitrate of potash can only be obtained by industrial operations on a large scale.

surfaces, part of which become uneven and rounded, while the rest is acute and specular. While defective portions of the crystals are completed to regularity, others of regular shape become irregular.

The crystals of certain substances are subject to be disfigured by fissures, especially when they are come to a certain size, and these fissures, which are produced by changes of temperature in the solution do not correspond with the natural cleavages. Crystals kept out of solution are free from such alterations. The change of summer and winter temperature has not visibly affected a collection of several thousand crystals, preserved in an unheated room. As, generally, the molecules of crystals are grouped in such a way that coherence is looser in a certain direction than in any other, there may exist, in some substances, a condition of tension in these molecules, so that, in consequence of a slight degree of expansion or contraction, rupture of continuity takes place in every direction. Among several hundreds of crystals of dithionate of strontia, not one has exceeded the size of a lentil without being disfigured by a number of irregular fissures. The fragments marked by these fissures are easily completed into crystals, which, however, as they increase, are soon cut through again by fissures. When affected by external mechanical action, the fragments of such crystals, as far as they are free from fissure, offer a notable degree of resistance. These fractures do not generally extend through the whole dimensions of a crystal. In this last case a continuous crust is never again formed around the crystal, the fissure persisting as its volume increases.

SPONTANEOUS DECOMPOSITION OF CRYSTALS.—Many crystals lose their water of crystallization even under ordinary temperatures, being thus easily subject to decomposition. This quality is so variable in intensity, that no distinct limits can be traced to its action, the more as the loss of water of crystallized hydrates depends, in some circumstances, as much on the pressure and on the hygrometric condition of the atmosphere, as on the degree of temperature. Crystallized substances, not losing any water under open air and under a certain temperature, lose it in a short time and under the same temperature when placed under the air-pump, or in an enclosed space, above substances attracting water, as sulphuric acid, or chloride of calcium. The bi-basic sulphate of nickel and potash, with six molecules of water, does not lose the least portion of it,

when subject during some time to a temperature of 100°C. The highest hydrate of arseniate of soda exposed to a temperature of 100°C., is reduced to powder within a few hours.

The greater number of crystallized substances, subject to spontaneous decomposition by loss of water in open air, are entirely reduced to powder. Some few hydrates having lost part of their water, preserve their original form, but lose their pellucidity. The fine crystals obtained from a mixture of the solutions of the sulphates of cobalt and zinc are soon decomposed without notable loss of consistence, their surfaces even remaining faintly bright. The same is the case with the crystals of sub-sulphate of lead, iron-alum, bi-basic sulphate of soda and lithium, &c. Some substances, as sulphate of copper, chrome alum, ferro-cyanide of sodium, etc., slowly decomposed in the open air, remain unaltered when carefully protected against its destructive action. Kept under hermetically closed glass bells, such crystals remain unaltered for 10 to 12 years. The resistance to the destructive action of air, may, in some few cases, be increased by admixture to the solution from which the crystals are obtained, of a solution of an isomorphous combination offering more resistance to this destructive action. The progressing decomposition of sub-sulphate of lead may be avoided by mixing the solution with a small proportion of isomorphous sulphates, as those of lime or strontia.

Iron-alum, a substance extremely subject to decomposition, when a little alumina-alum is added to its solution, may be so far secured against destructive agents, that its crystals remain unimpaired within a closed space. The uncommonly beautiful crystals of formiate of copper are soon decomposed into a white powder, even within a hermetically closed space. An admixture of some formiate of baryta or strontia, both crystallizing in variable proportions, unite with the formiate of copper, without altering its crystalline form, and impart to this last salt the power to preserve its integrity within a closed space. This last case is the more remarkable as the formiates of baryta and strontia crystallize in forms of the rhombic system, without being isomorphous, while the crystals of formiate of copper, either pure or mixed with the above named formiates, are monoclinous and isomorphous.

ACTION OF LIGHT.—Many facts concerning this action, especially on silver-salts, have been published. Formiate of lime exposed

during a long time to direct sunlight undergoes chemical alteration attended with mechanical destruction. A number of splinters are loosened from the crystals and projected with a certain degree of violence, no doubt by gaseous substances developing within the crystals. These being preserved in hermetically closed glasses, this development of gas can only be ascribed to internal molecular movements under the action of light. Large crystals of bi-basic formiates of copper and strontia placed under the same circumstances showed extensive black spots, and within some months became completely black. This alteration penetrating to the very centre of the crystals, affected neither their consistency, nor the very striking brightness of their surfaces. A similar mechanical action of light has been ascertained on formiate of cadmium, and on nitro-acetate of strontia. The crystals of oxalo-chromate of potash, pure or mixed with the bi-basic oxalate of ammonia and chromium, become opaque by exposure to light, without suffering further alteration. The bi-basic oxalate of chromium and ammonia is not altered by light.

FIRST FORMATION OF CRYSTALS.—The only rational and invariably successful way of obtaining isolated, not over-minute, and correctly formed crystals, whose volume may be progressively increased, is the method long ago commended by Leblanc, by spontaneous evaporation of solutions. Saturated solutions mixed with some little water, to retard the instantaneous formation of crystals, are placed in shallow dishes with flat bottoms and left to absolute repose. The size of the first formed crystals within a certain space of time depends on the volume of the solutions within them. When left in undisturbed repose, conditions of super-saturation, most favourable to the first formation of crystals, nearly constantly isolated individuals, fit for further increase, are found among the crystalline aggregations. Even crystals of difficultly soluble substances may come to notable dimensions in the course of beginning crystallization; it is, indeed, the only way of obtaining such substances under the form of isolated individuals fit for further progressive increase. Hot saturated solutions of easily soluble substances, when allowed to cool, give rise at the same time, to very voluminous compound crystals, provided the due degree of concentration has been found out, and also to isolated individuals. Generally, however, such crystals are imperfect in structure, these imperfections becoming more and more striking as they increase in

size, nor are they possessed of the degree of pellucidity proper to these substances. In over-saturated, as in hot cooling solutions, an over-hurried crystallization may take place, being indicated by the notable increase of crystals in a short period. In both cases the process of crystallization goes on more rapidly than within a not over-saturated solution left to spontaneous evaporation. The regular formation of any crystal seems to depend less on the celerity of the minimal particles deposited around the original nucleus, than on other disturbing circumstances. In an over-saturated solution of constant temperature, no movements take place capable of disturbing the normal deposition of fixed particles, set free on the surface of crystals in way of increase. The periods of repose, as those of disturbance, leave distinctly perceivable traces on crystals, especially on large and pellucid ones, whose increase has required a long period of time.